COMPARATIVE EVALUATION OF SIX DIFFERENT GRANULAR ACTIVATED CARBON FOR TCP REMOVAL USING RAPID SMALL SCALE COLUMN TEST

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DEDICATED

To

My Mother, Rae Harada:
Thank you for your unconditional love and support,
for pushing me through school,
and for all that you have sacrificed for me.
None of this would be possible without you.

My Father, Perry Harada:
Thank you for your unconditional love and support,
for teaching me to always be humble
and to always show respect,
and for sharing your humor and passion for music with me.
Proud to be a Harada.

My Aunty, Roanne Tsutsui:
Thank you for all you have done for me in my life,
for your help throughout my education,
for sharing your knowledge about life,
and most importantly, for accepting me like a son.
You are the best aunty ever.

Uncle Jay:
Thank you for all your love and for being my #1 fan.
You are everything I could ask in an uncle

Uncle Kenny:
Can't even begin to say how thankful I am to have you as an uncle.
I hope I made you proud, as a runner and as a person.

Uncle Roy:
Thank you for all your kindness.
I appreciate your always letting me stay over and helping me out.

Grandma:
Thank you for being the best grandma ever.
The goodies and ice cream money always hit the spot,
but it meant more to me just to visit you.
Love, Bryce-Man.

Grandpa:
Thank you for being the best grandpa in the universe.
I would give up everything just to see you again.
I loved going to KTA with you, and enjoyed hearing the same stories.
You could always bring a smile to my face.
I know one day we will be together again.

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and for giving me all your love and support;
it was unconditional for the most part, I think.
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and for putting up with me and my stressed-out self.
You could always brighten the darkest of days.

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ABSTRACT

A Constant Diffusivity-Rapid Small-Scale Column Test (CD-RSSCT) was performed to estimate the Granular Activated Carbon (GAC) usage rates of six different activated carbons for 1,2,3-Trichloropropane (TCP) removal. TCP is a synthetic chemical compound contained in industrial solvents and soil fumigants and is believed to be a human carcinogen. The State of Hawaii's current maximum contaminant level (MCL) for TCP is 600 parts per trillion (ppt), but consideration is being given to lower this MCL to 5 ppt. GAC adsorption is an efficient water treatment technique used to remove natural and synthetic organic compounds, chlorine, and some metals. The GAC is housed in contact columns at water treatment facilities. For this research, three separate Board of Water Supply (BWS) water treatment facilities on Oahu were selected as water sources for GAC adsorption tests. This project was conducted in collaboration with AECOM, a multinational consulting engineering firm with a branch office in Honolulu, Hawaii.

The objectives of this study were to determine whether any GAC could meet the possible new 5 ppt MCL for TCP, and if so, which type of GAC would be the most effective for TCP removal. In addition, as a preliminary step, it was necessary to create a method to quantify TCP at the 1 ppt level in order to conduct the study. This was accomplished by modifying an EPA method; this is the first such achievement in Hawaii. The GAC type that is able to treat the most bed-volumes at the selected breakthrough points was determined and recommended to replace the currently GAC used in Hawaii's water treatment facilities.

From the RSSCT results, numerous key findings were made. (1) Any of the 6 GACs tested can meet the new possible MCL of 5 ppt for TCP, (2) GAC C, the currently GAC used, was by far the least effective GAC in each of the three water well sites, (3) there was no one GAC that was the most effective for all three well sites; therefore, it is necessary to find a most effective GAC type specific to the well site, (4) the most effective GAC for Kunia I was GAC A/B and D, for Waipahu III was GAC E, and for Mililani I was GAC A/B, (5) the smaller the GAC particle size, the less effective the GAC was, (6)

the water matrix affected TCP adsorption, and (7) along with TCP, EDB and DBCP removal will also be taken into consideration for the GAC selection. The findings from this RSSCT study are of great value and significance. The fact that current GAC was the least effective is very insightful because it means that the selection of any of the other GACs would improve the GAC process performance in the field. Replacing the current GAC unit with a more effective one means the GAC units would need to be changed less frequently, thus saving on maintenance and operating costs.

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1 INTRODUCTION

1.1 Project Background

A granular activated carbon (GAC) water treatment study was conducted to evaluate six different types of granular activated carbons and determine their ability to absorb 1,2,3-Trichloropropane (TCP), a hazardous chemical compound found in Hawaii's drinking water aquifers. Water samples from three separate Board of Water Supply well source sites on Oahu were tested in this study.

Life cycle analysis of the GAC adsorber is dependent on the complex, non-steady state, mass transfer, adsorption capacity of the specific contaminant, GAC type, and the site-specific characteristics of the water matrix (Fotta 2012). Although GAC is an effective technique for removal of toxic organics from drinking water or wastewater and typically the best method for TCP removal (Veatch 2008), it is a relatively expensive process. Full scale GAC models are usually scaled to pilot scale models; these are, however, time consuming, expensive, and require ample supply of water. For this reason, a quicker and more economical method was designed that could model a full-scale GAC unit from a bench-scale test using small-scale columns. This bench-scale test, developed by J.C. Crittenden, is called the rapid small-scale column test (RSSCT) (Crittenden, Berrigan et al. 1986, Corwin and Summers 2010).

Based on the RSSCT results (Crittenden, Berrigan et al. 1986, Crittenden, Berrigan et al. 1987, Crittenden, Reddy et al. 1991), this GAC system was determined to be fully scalable. Therefore, this RSSCT method was used to compare the adsorption performance of various GAC types and to determine the number of bed-volumes of contaminated water that can be treated before reaching breakthrough limits in the actual water treatment. RSSCT is explained in detail in **section 2.3**.

RSSCT is a low-cost, time-efficient, and simple technique. However, TCP only has a low-moderate adsorption capacity for GAC. Hence, a larger GAC treatment system may have to be used to be effective, which would increase treatment costs (Glenn Dombeck and Borg , Tratnyek, Sarathy et al. 2008, Molnaa 2003).

The four main advantages of the RSSCT are:

1. It requires less time compared to that of pilot models.
2. It does not require extensive isotherm or kinetic studies as do some mathematical prediction models.
3. It does not require a large quantity of water, thus making it suitable to carry out experimentally in a laboratory.
4. It is more cost efficient compared to other models.

1.2 **Problem Statement**

1,2,3-Trichloropropane (TCP) was introduced to Hawaii in 1948 as an impurity found in soil fumigants used in pineapple fields. It was in the late 1970's that all TCP-containing products were banned from use in Hawaii due to its potential as a human carcinogen (Eric P. Hooker, Keri G. Fulcher et al. 2012). Although it had not been used in Hawaii since 1977, TCP contamination persisted in Hawaii's groundwater – a major health concern as this groundwater was used for human consumption as drinking water. It was necessary, therefore, that a method of TCP removal from the groundwater be designed and implemented. Granular activated carbon (GAC) adsorption was chosen as the treatment technique due to its efficiency. This GAC adsorption technique has been used at water treatment facilities for some time and as technology advanced over the years, different improved GAC prototypes were designed. Several of these prototypes, along with the GAC model currently used by the Board of Water Supply, were tested to determine which GAC model was the most effective for TCP removal.

1.3 **Objective**

The objectives of this study were to determine whether any GAC could meet the possible new 5 ppt MCL for TCP, and if so, which type of GAC would be the most effective for TCP removal from Hawaii's groundwater. This was accomplished by modifying an EPA method, a first such achievement in Hawaii. The GAC type that is able to treat the most bed-volumes at the selected breakthrough limits would be determined to be the most effective, and this GAC model would be recommended as a replacement for the current GAC system used in Hawaii's water treatment facilities.

1.4 Selected GACs and Water Well Sites

The following GACs were selected for analysis:

GAC ID	GAC Name
A/B	Calgon coconut shell carbon OLC 12x40
C	Jacobi direct-activated coal based carbon 8x30 (currently used by BWS)
D	Siemens coconut shell carbon C12x30
E	Siemens enhanced coconut shell carbon CX12x30
F	Calgon carbon coal based carbon F400 12x40
G	Jacobi coconut shell carbon 12x40

Table 1: Six Carbon Types Used

The GAC identifications and corresponding names are given in **Table 1**. Six different GACs, labeled A/B through G, were selected and compared. The numbers located after the GAC name indicate the full-scale mesh size. A GAC with "12x40" means that the GAC particles pass through a No. 12 sieve (1.68 mm), but are retained on a No. 40 sieve (0.425 mm). The selected GACs were from one of three manufacturers: Calgon, Jacobi, and Siemens. The Siemens and Calgon GACs were selected based on each company's experience with TCP treatment, their ability to consistently provide GAC in the quantities necessary, and a literature review.

The following three BWS well sites on Oahu were selected for the study:

1. Kunia Wells I GAC Water Treatment Facility
2. Mililani Wells I GAC Water Treatment Facility
3. Waipahu Wells III GAC Water Treatment Facility

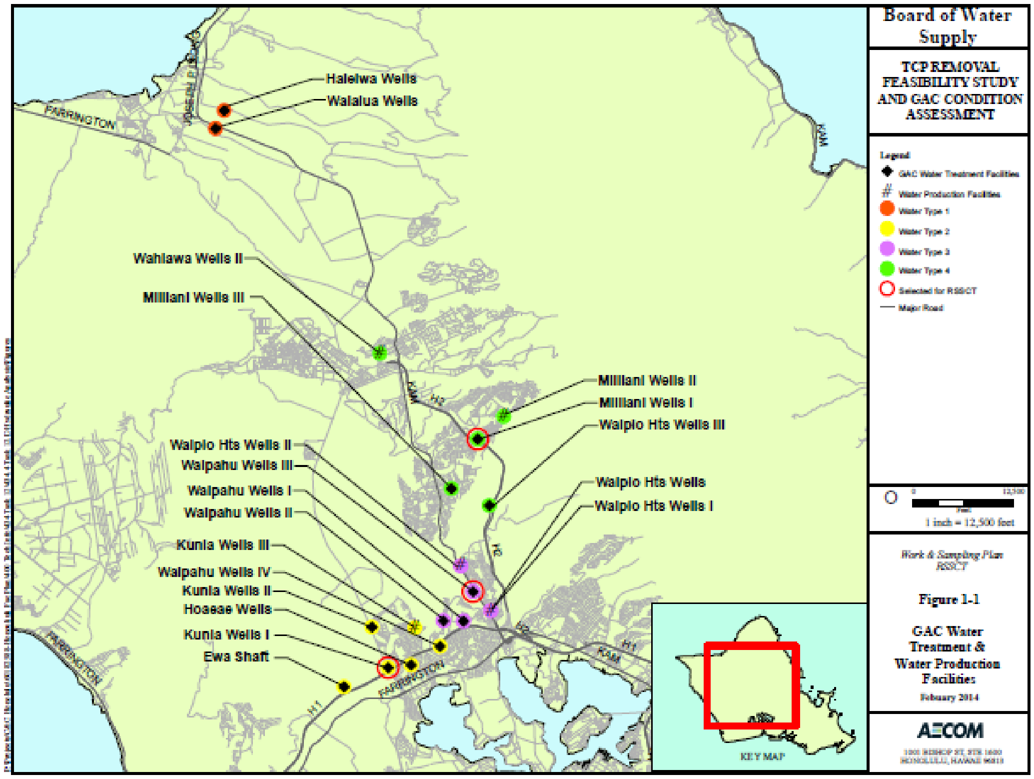


Figure 1: Map of GAC Water Treatment Facilities

A map of the GAC water treatment facilities located in central Oahu, including the three selected BWS wells, is shown in **Figure 1** (AECOM 2014). The three well sites were selected for several reasons. All three well sites have:

- Existing GAC treatment systems with room for expansion;
- Relatively elevated TCP concentrations;
- Representation of one of the three distinct cation-anion water types identified for all the wells in the study area (excluding Waialua Wells GAC Water Treatment Facility and Haleiwa Wells GAC Water Treatment Facility on the North Shore); and
- Concentrations of dissolved organic carbons typical for all the wells in the study area.

2 BACKGROUND

2.1 1, 2, 3-Trichloropropane (TCP)

2.1.1 What is TCP?

1,2,3-Trichloropropane (TCP) is a synthetic chlorinated hydrocarbon with a high chemical stability (Samin and Janssen 2012). It is also known as allyl trichloride, glycerol trichlorohydrin, and trichlorohydrin (ATSDR 1995, Administration 2013), with the chemical formula $C_3H_5Cl_3$. Its chemical structure is shown below in **Figure 2** (F. Bianchi, M. Careri et al. 2007).

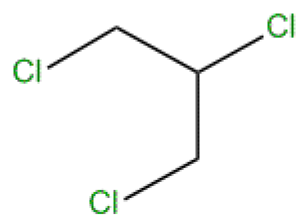


Figure 2: TCP Chemical Structure

It is characterized by being colorless, heavy, and highly volatile with a sweet and strong odor. Although its main use is to combine with other chemicals to make other chemical compounds, it was also widely used as an industrial solvent, paint remover, cleaning agent, and fumigant (ATSDR 1992).

TCP was an impurity contained in the Shell Chemical Company soil fumigant product, "D-D", which was used in Hawaii between 1948 and 1977. It was discontinued due to its potential as a human carcinogen (see **section 2.1.3**). Because of TCPs inability to decompose naturally into the environment, it is still present in Hawaii's groundwater. This is explained in **section 2.1.4.**

In 2005, the State of Hawaii established a statewide maximum contaminant level (MCL) of 0.6 ppb (2011). It has been proposed that Hawaii significantly lower its MCL for TCP to equal the CDPH's notification level of 5 ppt (2010).

The physical and chemical properties of TCP are shown below in **Figure 3** (Agency 2013).

Property	Value
CAS Number	96-18-4
Physical Description (at room temperature)	Colorless to straw-colored liquid
Molecular weight (g/mol)	147.43
Water solubility at 20°C (mg/L)	1,750 (slightly soluble)
Boiling point (°C)	156.8
Vapor pressure at 25°C (mm Hg)	3.1
Specific gravity	1.39
Octanol-water partition coefficient (log K_{ow})	1.98 to 2.27 (temperature dependent)
Soil organic carbon-water partition coefficient (log K_{oc})	1.70 to 1.99 (temperature dependent)
Henry's law constant at 25°C (atm-m^3/mol)	3.43×10^{-4}

Notes: g/mol – gram per mole; mg/L – milligrams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.

Figure 3: Physical and Chemical Properties of TCP

2.1.2 TCP Importance

TCP is a groundwater contaminant that is a suspected human carcinogen. This chemical compound is persistent in Oahu's groundwater aquifers and is a cause of concern to the general public's health. A cost effective and feasible method for TCP removal from contaminated water is imperative. Several options for removal are available, but GAC is being used as the method of choice for the removal of TCP contamination in Oahu's groundwater.

2.1.3 TCP Health Side Effects

TCP is believed to be a human carcinogen; there are no studies, however, proving that TCP is cancerous in humans. The only laboratory studies conducted were performed on animals and through in vitro testing. In these animal studies, it was found that long term effects of TCP exposure include bodyweight fluctuation, kidney problems, and increased risk of tumors (ATSDR 1992, Agency 2013). The EPA classifies TCP as "likely to be carcinogen to humans" ((IRIS) 2009), the U.S. Department of Health and Human Services anticipates TCP to be a probable human carcinogen based on carcinogenic effects on experimental animals ((DHHS) 2011), and the National Institute for Occupational Safety and Health (NIOSH) classifies TCP as a potential occupational carcinogen ((NIOSH) 2010).

Short term effects in humans exposed to TCP levels of 50 – 100 ppm over an 8-hour time span were throat and eye irritation. It is unknown what exposure to low levels of TCP level over a long period of time would be. The main health effect of TCP in both animals and humans was impairment of the respiratory system (ATSDR 1995).

2.1.4 TCP in the Environment and Groundwater Contamination

In the atmosphere, TCP is predicted to only exist in the gas phase. When TCP is exposed to sunlight, it breaks down in the air by a reaction with hydroxyl radicals. It possesses a half-life of 15 - 46 days, thus as little as 7% of the original TCP molecules will remain in the air after two months ((HSDB) 2009, (DHHS) 2011, Samin and Janssen 2012).

In the liquid phase, TCP is unlikely to sorb into soil because of its low soil organic carbon-water partition coefficient. Consequently, the TCP molecules either readily evaporate from the soil surface or leach through the soil into the groundwater (ATSDR 1992, ATSDR 1995, (HSDB) 2009). Since TCP in its pure form is a Dense Non Aqueous Phase Liquid (DNAPL), it is both immiscible and denser than water. This allows it to settle at the bottom of the aquifer where very minimal TCP evaporation occurs. There, the TCP molecules accumulate over time ((Cal/EPA) 2009), and it is the reason why TCP is still present in Oahu’s groundwater aquifers. TCP’s low abiotic and biotic degradation rates contribute to its persistence in the groundwater. Because of this, however, TCP is less likely to absorb into plants, fishes, and other aquatic organisms (ATSDR 1992).

There is no evidence that TCP can decompose naturally, but it may under favorable conditions (Stepek 2009). Proper remediation techniques are vital to ensure the safety of drinking water.

2.1.5 TCP Exposure

The main sources of TCP exposure in order of likeliness to occur are:

1. Inhalation via contaminated air
2. Ingestion via drinking contaminated water
3. Dermal/Ingestion via contaminated soil
4. Being in contaminated facilities

TCP exposure is most evident near a hazardous waste disposal site where TCP is not stored properly and in areas of TCP spillage. It is not a common compound found in the environment (air, water, soil). Low concentrations have been found in some rivers, bays, groundwater, wells, and hazardous waste sites (ATSDR 1992).

2.1.6 TCP Introduction to Hawaii

As stated earlier, TCP was an impurity in the Shell Chemical Company soil fumigant product, “D-D”. The amount of TCP in the D-D mixture was estimated to range from 0.4 – 0.7% by weight; the actual values, however, might deviate from this range. Even though TCP accounted for a only a small percentage of the total D-D content, D-D was used at such high rates that TCP was being applied at quantities equal to or more than most pesticides. D-D was initially manufactured in 1942, but it wasn’t until 1948 that it was introduced to Hawaii. The Dole Company and Del Monte Corporation, two pineapple growers on Oahu, selected Shell’s D-D as its primary soil fumigant to control nematodes in the pineapple fields (26)[26]. In the late 1970s to early 1980s, after 20 - 30 years of use in the fields, D-D use was banned due to the TCP health risks (Eric P. Hooker, Keri G. Fulcher et al. 2012). It was reported that D-D has not been used on Hawaii’s pineapple fields since 1977, but because of TCPs inability to decompose naturally into the environment, it is still present in Hawaii’s groundwater.

Two companies, Shell and Dow, who manufactured these TCP containing fumigants, purposely left TCP and other hazardous waste impurities in their products and intentionally mislabeled their as products as “100% active” as a business tactic to avoid the cost of having to remove and dispose of their hazardous wastes. Because of this, many innocent farmers throughout the country unknowingly dumped millions of pounds of TCP and other hazardous impurities into the ground. Valuable groundwater was thus contaminated throughout the country and is the reason that TCP can be found in many drinking water wells today (26)[26].

Volatile organic contamination in Hawaii was first revealed following a spilling incident on April 7, 1977. On that day, approximately 1.9 m^3 of Ethylene Dibromide (EDB) was spilled within 18 meters of Kunia Well on Oahu. This was the first time the State of Hawaii faced the possibility of pesticide contamination of its groundwater. Laboratory analyses conducted a week after the incident showed EDB levels were not detectable. The EDB detection limit of the testing apparatus was 500 ng/L (0.5 ppb), so it was assumed that the contamination level, if any, was less than that amount. It was suspicious, however, that such a high volume of EDB spill tested no significant concentration levels in the groundwater. The EDB spill must have gone somewhere, and they needed to investigate further.

In May, 1979, California wells were discovered to be contaminated with 1,2-Dibromo-3-chloropropane (DBCP). Five states where DBCP was used (including Hawaii) were asked to test their water samples for DBCP. All 16 sites tested in Hawaii were negative for DBCP. The detection limit of the testing apparatus for DBCP was 130 ng/L (0.13 ppb) (Oki and Giambelluca 1987).

As equipment sensitivity improved, and sampling frequency and coverage increased, EDB and DBCP came to be detected in Hawaii's groundwater. In April, 1980, EDB and DBCP were discovered in the Del Monte Kunia Wells at concentrations of 0.5 - 11 ppb and 92 - 300 ppb, respectively. The wells were closed as a result of this discovery. **Figure 4** shows the 10 water wells closed due to the existence of DBCP and EDB (Oki and Giambelluca 1987).

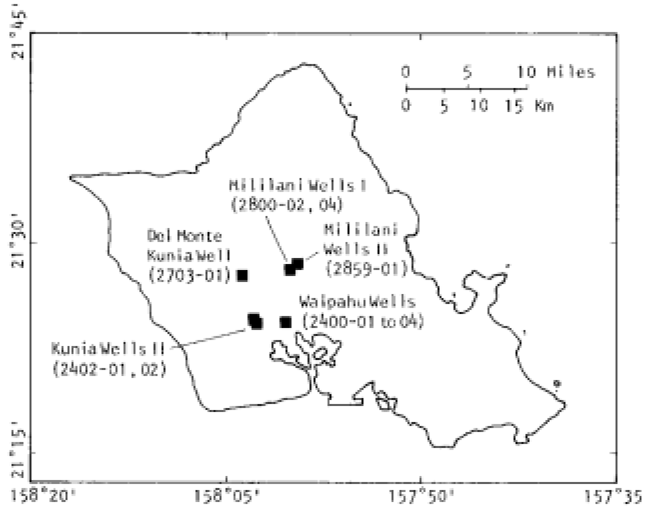


Figure 4: Closed Water Wells on Oahu from EDB and DBCP Discovery

It was not until September, 1983, that laboratory analyses for TCP contamination were conducted. It was discovered that all but one of the closed well sites were contaminated with TCP. Additionally, water samples from some central Oahu wells also showed TCP contamination. Water well TCP concentrations varied from 0.3 - 2.8 ppb (Oki and Giambelluca 1987).

Figure 5 (ATSDR 1992) below shows the number of National Priorities List (NPL) sites with TCP contamination. It can be seen that TCP contamination is uncommon, but 6 of the 8 contaminated sites were located in Hawaii.

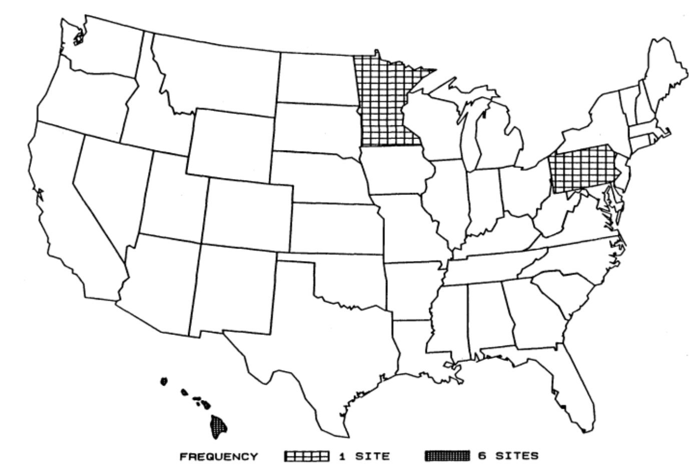


Figure 5: NPL Sites with TCP Contamination

2.1.7 California and Hawaii's TCP Regulations

The State of California currently does not have a statewide Maximum Contaminant Level (MCL), but the California Department of Public Health (CDPH) has a TCP notification level of 5 ppt. The CDPH is currently working on a MCL for TCP and is set to release this information for public comment in late 2014 or 2015. The current notification level will continue to be used to local agencies and consumers (2014). The California notification level of 5 ppt is based on a 1 in 10^{-6} lifetime excess cancer risk and a final public health goal of 0.7 ppt ((OEHHA) 2009). There is no federal MCL regulation for TCP (EPA 2013).

As mentioned earlier, the State of Hawaii has a MCL of 0.6 ppb (2011) although it has been suggested it be lowered to equal the CDPH's notification level of 5 ppt (2010).

2.1.8 Existing Federal and State Guidelines and Health Standards for TCP

The major existing federal and state health standards and guidelines for TCP are shown below:

- The EPA Integrated Risk Information System (IRIS) states a chronic oral reference dose of 4×10^{-3} mg/kg/day and chronic inhalation reference concentration of 3×10^{-4} mg/m^3 ((IRIS) 2009).
- The cancer risk assessment for TCP is based on an oral slope factor of 30 mg/kg/day ((IRIS) 2009).
- The EPA has established a 1-day health advisory of 0.6 mg/L and a 10-day health advisory of 0.6 mg/L for TCP in drinking water for a 10 kg child (EPA 2012a).
- The EPA established a residential soil screening level (SSL) of 5.0×10^{-3} mg/kg and an industrial SSL of 9.5 x 10-2 mg/kg. The soil-to-groundwater risk-based SSL is 2.8×10^{-7} mg/kg (EPA 2013).
- The Occupational Safety and Health Administration (OSHA) has established an industrial permissible exposure limit of 50 ppm based on exposure for 8 hours (Administration 2013).

- The National Institute of Occupational Safety and Health (NIOSH) has set a recommended exposure limit (REL) of 10 ppm and an immediately dangerous to life and health (IDLH) level of 100 ppm ((NIOSH) 2010).

2.1.9 TCP Detection Methods

The EPA Method 524.2 (Capillary Column GC/MS) was the method used in this study. Other main methods used for TCP detection are listed below:

- EPA Method 8260B – Gas chromatography (GC)/mass spectrometry (MS) for TCP detection in solid waste matrices (EPA 1996).
- EPA Method 504.1 – Microextraction and GC for TCP detection in groundwater and drinking water (EPA 1995).
- EPA Method 551.1 – Liquid-liquid extraction and GC with electron-capture detection for TCP detection in drinking water, water being treated, and the raw source water (EPA 1990).
- California DHS Method (Developed by CDPH) – Liquid-liquid extraction, MS/GC, purge and trap MS/GC for trace-level TCP detection in drinking water ((CDPH) 2002a, CDPH 2002b)
- EPA Method 524.2 – Capillary Column GC/MS for TCP detection in surface water, groundwater, and drinking water in any stage of water treatment (EPA 2009).

2.1.10 TCP Treatment (Sources)

Granular activated carbon (GAC) was chosen as the method for TCP removal in this study. This treatment is typically the best method for TCP removal (Veatch 2008), but the commonly used pilot model to study the effectiveness of the GAC system is very expensive. The RSSCT used in this study is low cost, time efficient, and simple. However, TCP only has a low-moderate adsorption capacity for GAC. Hence, a larger GAC treatment system may have to be used to be effective which would increase treatment costs (Glenn Dombeck and Borg , Tratnyek, Sarathy et al. 2008, Molnaa 2003)

Alternative TCP treatment methods include:

- Anaerobic reductive de-chlorination via hydrogen release compound (Tratnyek, Sarathy et al. 2008)
- Pump and treat reactive barriers
- In situ chemical oxidation and bioredimation
- Chemical oxidation with Fenton's reagent via bench-scale tests (Khan and Sermsai 2009).
- Soil vapor extraction (SVE)
- Ultraviolent (UV) radiation and chemical oxidation with potassium permanganate (Glenn Dombeck and Borg , (Cal/EPA) 2009)
- Oxidation process, known as HiPOx, which uses ozone and hydrogen peroxide via bench-scale tests (Glenn Dombeck and Borg)
- Use of genetically engineered strains of Rhodococcus under aerobic setting for complete TCP degradation (Samin and Janssen 2012)
- Remediation of chlorinated hydrocarbons include pump and treat, permeable reactive barriers, in-situ oxidation, biodegradation, and anaerobic reductive de-chlorination via hydrogen release compound (Agency 2013).

2.1.11 TCP Production and Disposal

There was an estimated 21 to 110 million pounds of TCP present worldwide in 1977. Although recent data on TCP production was not available, it can be produced via the following:

- chlorination of propylene;
- the addition of chlorine in allyl chloride;
- the reaction of thionyl chloride with glycerol;
- the reaction of phosphorous pentachloride with either 1, 3 – or 2, 3 – dichloropropanol; and

- as a byproduct of processes primarily used to produce other chemicals, including dichloropropene (a soil fumigant and nematode pesticide), propylene chlorohydrin, propylene oxide, dichlorohydrin, and glycerol (ATSDR 1992).

TCP has been identified as a hazardous waste by the EPA, and the disposal of this compound is regulated under the Resource Conservation and Recovery Act (RCRA). TCP can be disposed of in the following manner:

- atomization in a suitable incinerator equipped with appropriate effluent gas scrubbers (HSDB 1989)
- adsorption onto vermiculite, dry sand, earth, or similar material followed by disposal in a secured landfill (in cases of accidental spills) (HSDB 1989)
- land disposal – however, may no longer be allowed by the disposal regulations discussed above;
- in cases of waste water and sewage, through the use of activated sludge treatment processes (Matsui S, Sasaki T et al. 1975).

No data were found concerning the approximate amounts disposed by the various methods.

2.2 **Granular Activated Carbon (GAC)**

2.2.1 What is GAC?

Granular Activated Carbon (GAC) is a form of carbon made from raw organic materials with high carbon contents such as coal, coconut shells, lignite, and wood. GAC possesses the quality of low volume pores which provide a large surface area available for adsorption. The full-scale and small-scale GACs are shown in **Figure 7** and **Figure 7** respectively. Activated carbon is frequently used in water treatment and purification as the medium that absorbs the following:

- Organic, non-polar compounds
- Halogenated Compounds
- Odor

- Taste
- Various fermentation products
- Yeasts (EPA 2014).

Figure 6: Full-Scale Granular Activated Carbon

Figure 7: Small-Scale Granular Activated Carbon

2.2.2 Description of Processes

GAC acts as a good adsorbent medium because of its high surface area to volume ratio. This allows a large number of contaminant molecules to adhere to its surface area. Adsorption is the process by which molecules of a dissolved compound collect and adhere to a surface of a solid. In this case, the TCP adsorbs to the GAC surface. The carbon molecules in the GAC are activated by subjecting it to heat in the absence of oxygen. This activation increases the surface area of the GAC particles. One gram of activated carbon can have a surface area ranging from 500 - 1500 m^2 (Lenntech 2014). **Figure 8** (Jenoptik) shows how the contaminant adsorbs to the GAC.

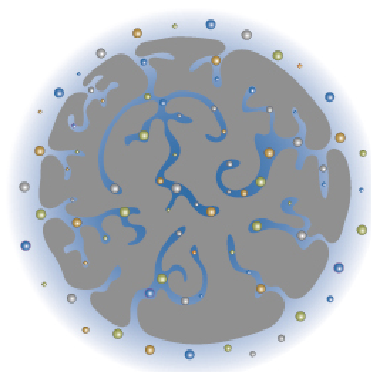


Figure 8: Granular Activated Carbon Adsorption Process

The tendency of a compound to adsorb is a function of the properties of the adsorbent (GAC), the adsorbate (TCP), and the liquid medium (water) (Weber 1993). Both TCP and GAC are hydrophobic compounds and thus the TCP will tend to adsorb to the GAC surface. The sorbate property that is the most associated with the adsorption of organic compounds is hydrophobicity. Hydrophobic compounds will tend to partition to the sorbent instead of staying in the liquid medium. It makes sense that the water solubility and octanol-water partition coefficient (K_{ow}) are good indicators of the adsorptivity of a compound. As seen in **Figure 3**, the water solubility at 20˚ C is 1.750 g/L and the log K_{OW} ranges from 1.98 to 2.27. These values indicate that TCP is slightly soluble in water, but only has a low-moderate adsorption capacity for GAC.

The contaminant-containing water is pumped through a column contain GAC and exits through a drainage tube. The temperature and nature of the constituent affect the adsorption capacity of the GAC. The contaminant adsorbs to the GAC surface layer until the entire surface area is covered. The contaminant thereafter has no room for further adsorption; as a result, all excess contaminants flow out through the column.

This GAC column tests work by the following process: As water is passed through the column containing GAC, the contaminants adsorb to the carbon particle's surface area, preventing them from passing through the column. The smaller the carbon particle size, the more carbon surface area there is per unit volume; therefore more contaminant can be adsorbed to the activated carbon. Once the contaminant particles have fully saturated the entire carbon surface, the contaminant can no longer adsorb to the carbon. The contaminant will start to flow out through the GAC column and out the effluent end. This process is known as breakthrough, explained in **section 2.2.5**. **Figure 9** (Noonan and Curtis 1990) shows the different zones in the carbon bed as water flows through. The equilibrium zone (zone of exhaustion) is the zone where the contaminant has fully saturated the adsorbent material. Mass transfer zone (MTZ) is the zone where the contaminant is adsorbing to the adsorbent, but full saturation has not yet occurred. The unused carbon zone is where the contaminant has not yet adsorbed to the adsorbent.

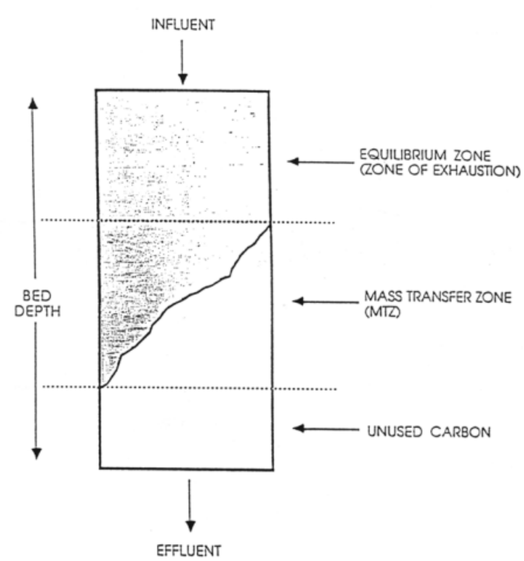


Figure 9: Flow Diagram of Zones in Carbon Bed

Figure 10 (Jenoptik) shows the relationship between the capacity of the adsorber to mass transfer. The smaller the diffusion rate, the slower the contaminant will adsorb relative to time, and the larger the MTZ will be. Good kinetic conditions will yield shorter MTZ. In this study, it was not necessary to reach complete breakthrough. Only a specified limit (1%, 5%, and 10% breakthrough) was necessary as shown in **Figure** 10. The column shown above the breakthrough curve is an example of a good adsorbent while the column below is an example of a poor adsorbent. The orange color indicates saturated absorbed material, the color gradient between orange and blue indicate the MTZ, and the blue color represents the unused carbon

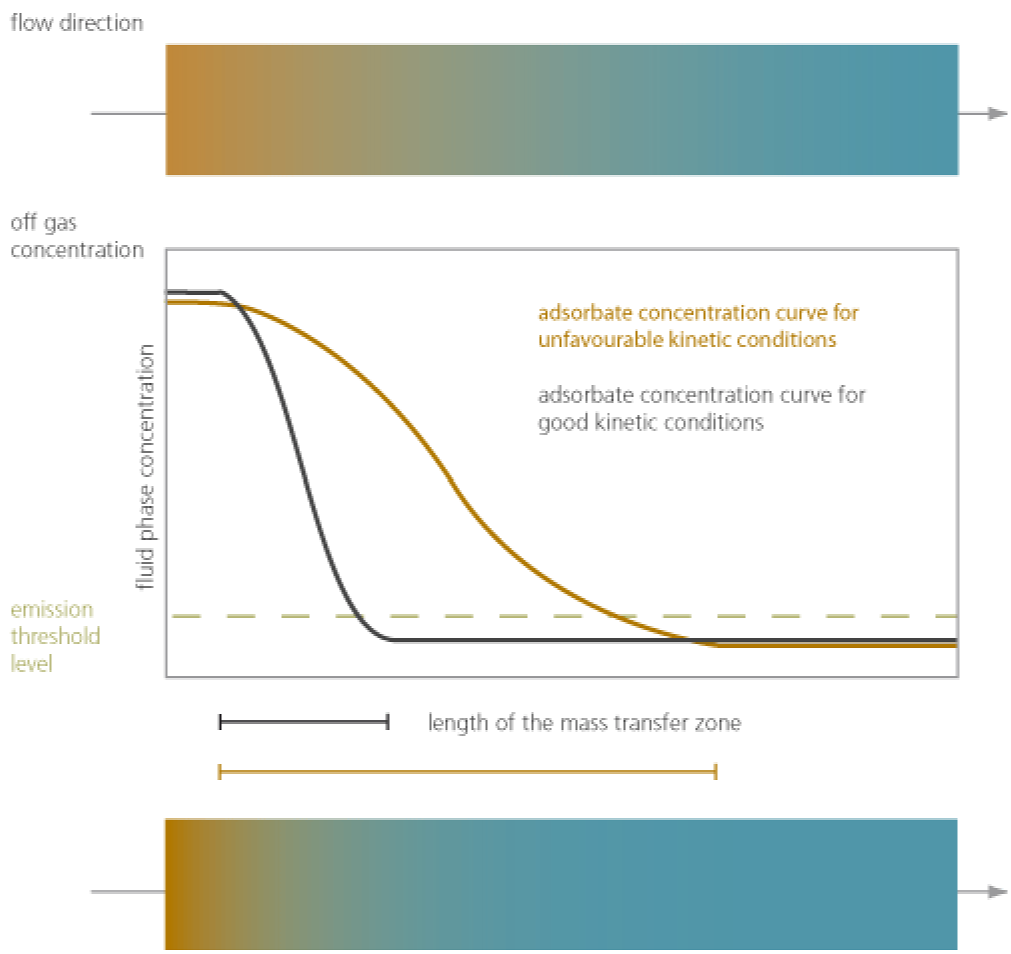


Figure 10: Mass Transfer in Adsorber

The TCP concentration coming out of the effluent end of the column will increase until it reaches the initial (influent) concentration that entered the column. The plot of relative concentration versus bed-volumes (or time) is called the breakthrough curve. Relative concentration is the effluent contaminant concentration divided by the initial influent concentration. Bed-volume is a unitless dimension that equals the total volume treated divided by the volume of the carbon bed.

GAC's uniformity coefficient is relatively large, C_u = 1.9, to encourage stratification after backwashing, minimize desorption, and premature breakthrough. Iodine and molasses numbers are often used to describe GAC content. These numbers represent the small and large pore volumes, respectively, in a GAC sample. American Water Works Association (AWWA) standards require a minimum iodine number of 500 (EPA 2014).

2.2.3 GAC Particle Sizes

Typically, GAC particle sizes range in diameter between 1.2 - 1.6 mm and in bed densities between 23 - 29 lb/ft^3, but is dependent on the materials and the manufacturing process used (EPA 2014). In our study, the GAC particles were sieved between sieve no. 12x40, 12x30, and 8x30. This corresponded to average GAC particles of 1.05 mm, 1.1375 mm, and 1.4875 mm, respectively.

The GAC in the small-scale columns were sieved between sieve no. 170x200, corresponding to in average particle size of 0.081 mm. The size of the GAC in the small-scale test was proportional to the full scale test.

2.2.4 GAC Treatment Units

There are two main options when implementing GAC as a filtration media into water treatment plants. They are post filtration adsorption and filtration adsorption.

1 Post-filtration adsorption – The GAC filter unit is located after the filtration process. This method receives higher quality water than its counterpart and its only purpose is to remove the dissolved organic compounds specified which in

this case, is TCP. Backwashing is not necessary unless excessive biological growth occurs. Because the GAC filter is in a separate unit for the filtration process, this method provides for easier maintenance of GAC and for the ability to design for specific adsorption circumstances. The drawback is its longer contact time and cost.

2 Filtration-adsorption – The GAC filter replaces some or all of the existing filter media. This method can also be used for turbidity removal, solid removal, and biological stabilization. Because the filtration-adsorption method is essentially replacing the existing filter media and not constructing a whole new unit, capital costs can be reduced. This method will have a shorter contact time. Its disadvantages include: more backwashing, greater carbon lost due to the increase in backwashing, and shorter filter run times which can in turn may increase costs (EPA 2014) .

These options are shown below in **Figure 11** and **Figure 12**.

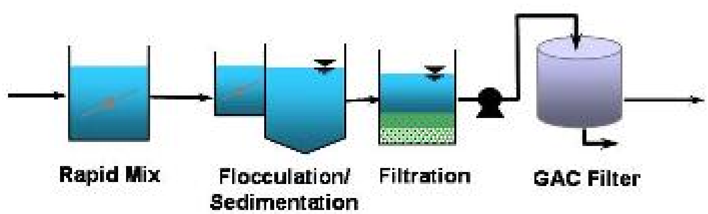


Figure 11: Post Filtration Adsorption Unit

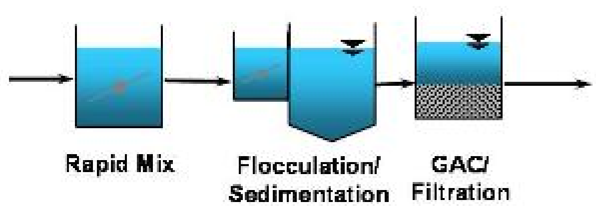


Figure 12: Filtration/Adsorption Unit

2.2.5 Key Concepts

Key concepts to understand the GAC process are:

1. Breakthrough – Time required (or bed-volumes) for the concentration of a contaminant in the effluent water of the GAC unit to exceed the treatment requirement. A general guideline to determine the GAC exhaustion is that if the effluent concentration is greater than the treatment requirement for over three consecutive days, the GAC is considered exhausted and must be replaced or regenerated.

2. Empty bed contact time (EBCT) – A measure of the time when the water to be treated is in contact with the treatment medium in a contact vessel. In short, it is the time the water remains in the column. It is calculated by dividing the empty bed-volume of the column, V, by the water flow rate, Q. There are three ways to achieve longer EBCTs: 1) by increasing the bed-volume, 2) by reducing the flow rate, or 3) a combination of both. The EBCT and the design flow rate control the amount of GAC required in the adsorption component. A longer EBCT can delay breakthrough and reduce the GAC replacement/regeneration frequency. The GAC column volume and depth can be determined once the optimum EBCT is set. Typical EBCTs for water treatment range between 5 to 25 minutes (EPA 2014).

3. Designed flow rate – the volume of water passing through the GAC column per unit time. The adsorption column is designed in accordance with the design flow rate. High flow rates are used for highly adsorbable compounds, but are not as important for less adsorbable compounds (EPA 2014).

4. Carbon Usage Rate (CUR) – Rate at which carbon is exhausted and need to replaced. Longer EBCTs and deeper column depths increase the CUR (EPA 2014).

2.2.6 GAC column configuration

GAC contactors can be configured in three ways:

1. Downflow fixed beds
   a. In-series – The first GAC unit in the series receives the highest contaminant concentrations, while the last unit receives the lowest. When GAC is removed from the first unit for regeneration, the next unit takes the influent concentrations. In-series units are good for water quality, but do not efficiently use the GAC.
   b. In-parallel – Each unit accepts the same flow and contaminant concentration. Numerous units can be run in parallel-staggered mode where each unit is at a different stage of carbon exhaustion. Effluent from each unit is blended so that individual units can be run beyond breakthrough and still meet the treatment goal. In-parallel units help to maximize GAC usage, but do not result in as good a water quality as in-series counterparts.
2. Upflow beds
   a. Fixed – Differs from downflow fixed beds by having the water enter through the bottom and exit through the top. It reduces error caused from air bubbles. The upflow fixed bed was the configuration selected for this RSSCT study.
   b. Expanded – Periodic bed expansion allow removal of suspended solids and enhancing segregation of small inactive suspended particles.
3. Pulsed beds

   Fresh GAC is added at the top of the unit while the exhausted GAC is removed at the bottom of the unit. Because of this protocol of continued refreshing of GAC, pulsed beds do not reach total breakthrough (EPA 2014).

2.2.7 Handling of Spent/Exhausted GAC

Once the GAC is exhausted/spent and removed from the column, it must be properly disposed of or regenerated. Disposed GAC can be a potential hazard due to the fact that desorption of the contaminant can occur and the contaminant can leach back into the aquifers and soils. Regeneration of GAC is preferred over disposal methods. Three common GAC regeneration methods are thermal, chemical, and steam; thermal regeneration is the most common (EPA 2014).

2.2.8 Adsorption Isotherms

The ability of a specific GAC to remove a particular contaminant can be modeled by GAC adsorption isotherms. This is of particular interest to carbon manufacturers who want to predict the adsorption capacity of a specified GAC to a contaminant. An adsorption isotherm describes the equilibrium between the adsorbent (GAC) and adsorbate (TCP). It is dependent on the molecular surface attraction, the total surface area per GAC unit weight, and the contaminant concentration (Corporation 1992).

Three mathematical expressions can be used to express the adsorption isotherms; the linear, Langmuir, and Freundlich equations (Lamichhane 2014).

Linear Adsorption Isotherm:

$$C^{*} = K_{d}C \qquad (1)$$

Where: C^{*}: mass of solute adsorbed per dry unit weight of solid (mg/kg)

C: concentration of solute in solution at equilibrium with the solid (mg/L)

K_d: distribution coefficient

Langmuir Adsorption Isotherm:

The Langmuir isotherm is based on the idea that a solid surface possesses a finite number of adsorption sites. Once all the sites are filled, the adsorbate will no longer adsorb any adsorbent from the solution and thus a maximum adsorbate concentration will be reached. Langmuir's equation is described as:

$$C_{s} = \frac{x}{m} = \frac{abC_{e}}{1 + bC_{e}} \qquad (2)$$

Where: Cs: solid-phase concentrations (mg/mg)

Ce: equilibrium liquid-phase concentration of sorbate (contaminant) (g/m^3)

a: empirical constant

b: saturation constant (m^3/g)

Ce/Cs plot as a function of Ce: slope (1/a) and the intercept (1/(a.b))

x: mass of contaminant (sorbate) sorbed (g)

m: mass of sorbent (g)

<u>Freundlich Adsorption Isotherm:</u>

The Freundlich isotherm is based on the idea that adsorption will continue as the concentration of adsorate increases. Adsorption will continue with increasing contaminant concentrations, but at a decreasing rate. Freundlich's equation is

$$C_s = \frac{x}{m} = K_f C_e^{\frac{1}{n}} \qquad (3)$$

Where: Cs: concentration of contaminant sorbed on solid surface (mg/mg),

x: mass of contaminant (sorbate) sorbed (g),

m: mass of sorbent (g),

K_f: the Freundlich sorption parameter,

n: empirical constant,

Ce: contaminant concentration in solution in equilibrium) (g/m^3)

These equations plot a relationship between the TCP concentration adsorbed on the GAC (Cs), and the equilibrium TCP concentration remaining in the solution (Ce). A best fit line and R^2 of the data are generated. The higher the adsorption capacity, the steeper the best fit line. The isotherm type with the highest R^2 value is the one chosen to model the adsorption capacity of a certain adsorbent and the contaminant adsorbate.

As mentioned earlier, TCP has a low-moderate adsorption capacity for GAC. It is assumed that complete breakthrough of TCP will occur in the GAC medium if TCP contaminated water is allowed to pass a GAC column bed for an extended period of time. The determination of the full adsorption isotherm of GAC and TCP is beyond the scope of this study; a 1%, 5%, and 10% breakthrough was therefore used. It was assumed that for constant diffusivity in RSSCT, the Freundlich isotherm equation was used to describe TCP behavior.

2.3 **Rapid Small Scale Column Test**

Rapid Small-Scale Column Test (RSSCT) was carried out in accordance with the American Society for Testing and Materials (ASTM) D-6586 – 03(2008) (Materials 2008) and "Design of Rapid Small-Scale Adsorption Tests for a Constant Diffusivity (Crittenden, Berrigan et al. 1986).

2.3.1 Approach

RSSCT is a method developed by J.C. Crittenden for the evaluation of GAC for the adsorption of soluble contamination from water. RSSCT uses the concept of scaling the hydrodynamics and mass transport of the full-sized GAC in the full-scale column to a smaller GAC in the small-scale column bench test (Westerhoff 2004). It achieves this scaling by using dimensionless parameters from the surface diffusion and dispersed-flow pore model (DFPSDM) (Crittenden, Berrigan et al. 1986, Crittenden, Berrigan et al. 1987), which uses many of the practices that occur in fixed-bed adsorption. DFPSDM devices cause the breakthrough curves of an adsorber to disperse and create similar mass transfer zones (MTZ) in the full-scale and small-scale columns, consequently resulting in similar breakthrough curves. Mechanisms used include axial dispersion and diffusion, external and internal mass transfer resistance, surface and pore diffusion, advective flow, and adsorption equilibrium (Crittenden, Berrigan et al. 1986).

The goal is to predict the adsorption of the contaminant onto the GAC in the actual water treatment plants through the RSSCT. This is achieved by passing the TCP contaminated water at a constant flow rate through a bed of GAC, testing the effluent water for the contaminant, and analyzing their breakthrough curves.

Two key assumptions must be made in order for RSSCT to be valid:

1. GAC properties must be the same for full-scale and small-scale test (e.g., adsorption capacity, bulk density, porosity).
2. The specified contaminant (TCP) and other compounds completing for adsorption sites must rely on the particle size in the same way.

The four main advantages of the RSSCT are:

1. It requires less time compared to that required by pilot studies.
2. It does not require extensive isotherm or kinetic studies as do some mathematical prediction models.
3. It does not require a large volume of contaminated water, thus making it amenable and convenient to carry out experimentally in a laboratory.
4. It is cost efficient compared to other models.

There are two types of commonly used RSSCT design approaches: constant diffusivity test (CD-RSSCT) and proportional diffusivity test (PD-RSSCT). The CD-RSSCT is often used for low natural organic matter (NOM) water to predict removal of a specified contaminant, while PD-RSSCT has been shown to predict removal of NOM and disinfected byproduct (DBP) (Crittenden, Reddy et al. 1991, Summers, Hooper et al. 1995). It is still uncertain which of the two tests is more appropriate for removal of trace organic compounds; for this study, however, the constant diffusivity test was used.

All types of water can be subjected to this procedure, including highly contaminated water, potable water, wastewater, sanitary wastes, and effluent waters.

2.3.2 Development of Scaling Equations

Six independent dimensionless parameters, $Dg_{s,I}$, $Dg_{p,I}$, $Ed_{s,I}$, $Ed_{p,I}$, Pe_i, and St_i need to be held constant in order for the full-scale adsorber to be correctly scaled to the small-scale version. These parameters are defined in Error! Reference source not found.**2** (Fotta 2012) where:

ε_p is the intra-particle porosity, ε is the bed porosity, D_p is the pore diffusion coefficient, t is the fluid residence time in packed bed, d_p is the particle diameter, D_s is the surface diffusivity, C_F is the capacity factor, L is the bed length, v is the fluid velocity, D_x is the dispersion coefficient, k_f is the film mass transfer coefficient, q_0 is the solid phase equilibrium concentration, C_0 is the influent phase concentration, and ρ_b is the density.

The capacity factor is defined by:

$$C_F = \frac{q_0 \times \rho_b}{C_0 \times \varepsilon} \tag{4}$$

Table 2: Independent Dimensionless Parameters for RSSCT Scaling Process

Dimensionless Number	Equation	Allows Matching of
Pore solute distribution parameter	$D_g = \frac{\varepsilon_p(1-\varepsilon)}{\varepsilon}$	Local equilibrium
Pore diffusion modulus	$Ed = \frac{4D_p \times D_g \times t}{d_p^2}$	Intraparticle mass transfer
Surface diffusion modulus	$Ed_s = \frac{4D_s \times C_F \times t}{d_p^2}$	Intraparticle mass transfer
Peclet number	$Pe = \frac{L \times v}{D_x}$	Axial dispersion
Stanton number	$St = \frac{2k_f \times (1-\varepsilon) \times t}{d_p \times \varepsilon}$	Film mass transfer

The intra-particle diffusivity is independent of carbon particle radius, and small-scale and full-scale models have identical Reynold's numbers. Thus, the small-scale test can simulate the specified full-scale model.

To find scaling relationships, some assumptions were made for the following parameters that affect the GAC performance: backwashing, physical characteristics of the GAC, adsorption equilibrium capacity, and adsorption kinetics. Changing any of these parameters could result in poor representation of full-scale performance from RSSCT.

Backwashing was not used in scaling equations; however, simulation of backwashing in RSSCT may be possible if GAC particle distribution in RSSCT and full-scale models are identical. Equilibrium and adsorption capacity are assumed to be identical in small-scale and full-scale models. Isotherm capacity of RSSCT GAC and unground full-scale GAC were also identical (Berrigan 1985). The physical characteristics of GAC (apparent and bulk density and bed void fraction) were not used in scaling equations because studies have shown that they have little impact on performance (Berrigan 1985, Berrigan 1985). Adsorption kinetics, pore and surface diffusion coefficients D_s and D_p, respectively, have been found to be independent of particle size only when pore and surface diffusivities in small-scale test were identical to that in the full-scale test (Dobrzelewski 1985, Crittenden, Berrigan et al. 1986).

Insoluble material such as fats, oils, greases, suspended solids, and emulsions must be removed before testing starts. These insoluble materials obstruct the contaminant's adsorption to the GAC. Air bubbles also must be removed because it interferes with water flow.

The following equations can describe the relationship between small and large columns:

$$\frac{EBCT_{sc}}{EBCT_{lc}} = \left(\frac{R_{sc}}{R_{lc}}\right)^2 = \frac{t_{sc}}{t_{lc}} \tag{5}$$

Where: $EBCT_{sc}$ and $EBCT_{lc}$ are the empty bed contact times for the small scale and full scale column, respectively;

R_{sc} and R_{lc} are the carbon particle radii for the small and full scale column, respectively;

t_{sc} and t_{lc} are the elapsed time required to conduct the small and full scale test, respectively; and

V_{sc} and V_{lc} are the hydraulic loading in the small and large column, respectively.

In order for **equation 2** to be valid, the solute distribution parameters, Dg_i, were assumed to be identical for RSSCT and full-scale tests.

Stanton numbers, St_i, was identical in RSSCT and full-scale tests based on **equation 6** relating liquid-phase mass transfer coefficients which were achieved based on identical Sherwood numbers. The general equation of liquid-phase mass transfer correlations is shown in **equation 7**. Determination for film transfer coefficients in fixed-bed adsorbers was found to be correct (Williamson 1963, E. J. Wilson 1966)

$$\frac{k_{f,sc}}{k_{f,lc}} = \frac{R_{lc}}{R_{sc}} \tag{6}$$

$$Sh_i = F(Re_i, Sc_i) \tag{7}$$

Where: Sh_i is the Sherwood number and Re_i is the Reynolds number.

The hydraulic loading and particle size of full-scale and small-scale tests are represented by **equation 8**. This equation guarantees identical Reynolds numbers for full-scale and small-scale tests.

$$\frac{V_{sc}}{V_{lc}} = \frac{R_{lc}}{R_{sc}} \tag{8}$$

Where: V_{sc} and V_{lc} are the hydraulic loading in the small and large column respectively.

It is recommended that the RSSCT be compared to a pilot point column test. This would help in the selection of the RSSCT design variables and reduce the chance of calculation mistakes (Crittenden, Berrigan et al. 1986). However, it was not done in this particular study.

The proper GAC column volume and preparation methods are crucial to the success of the RSSCT. To avoid channeling of GAC particles, the minimum small scale GAC column diameter should be 50 particle diameters. In this experiment, all small scale GACs besides run #11 (mesh size comparison) had mesh sizes of no. 170 X 200 (0.088 by 0.075 mm) which fulfill the minimum column diameter requirement.

Breakthrough curves can be generated based on the water flow rate to the GAC column, the time each water sample was tested, and the concentration of contaminant in the effluent water at a specified time.

2.3.3 Drawbacks

Compared to pilot point studies, the RSSCT does not have an actively running evaluation of issues that can affect the GAC performance. These issues include:

- Bacterial colonizing on GAC (Owen, Chowdbury et al. 1996)
- Long term fouling of GAC (Knappe, Snoeyink et al. 1997)

3 METHODS AND PROCEDURES

3.1 Water Sample Transport and Preparation

Raw water samples from each well site were collected in five gallon food grade polyethylene containers. A total of twenty water containers were used. The samples were collected directly from the operating well on site. The selected well sites have multiple individual wells within the site to meet peak flow demand and operational redundancy. Water was collected on a weekly basis and was transported directly to the laboratory. Water containers in use were placed into a large refrigerator set at 10˚C and the remaining containers were stored in a cold room at 4˚C.

Each GAC column was connected to a RSSCT metering pump and used one water container. This meant that if a run consisted of three GAC columns, then three water containers were used. This protocol reduces error caused by a GAC column apparatus malfunction or a failure to replace water. Water containers stored in the cold room were used to feed containers in the refrigerator as water levels lowered.

To prevent sample contamination, workers were required to wear sterile gloves during sample collection and extractions in the lab.

3.2 Analytical Details

Water samples from the RSSCT column effluent were designed to be collected in set time intervals determined by the GAC particle size. However, because different GAC types (thus, different particle sizes) were run at the same time, the time intervals were not all at the same. If three different GACs types were run at once, there would be eight sampling times a day. Each sample took between 25 - 70 minutes to collect so this was an unreasonable task to ask of the 2- 3 workers. Instead, every run was collected three times per day at 12:00 am, 8:00 am, and 4:00 pm. The length of each run ranged from 14 - 20 days, varying due to water source and carbon type.

The samples were submitted for laboratory analysis by CDPH Modified United States Environmental Protection Agency Method 524.2 by purge and trap Gas Chromatography (GC) and Mass Spectrometry (MS). This lab analysis was carried out by UH-WRRC; however, because UH-WRRC lab is not state certified with the modified EPA Method 524.2, the samples were also analyzed by BC Laboratories, an environmental laboratory located in Bakersfield, California, that is state certified to perform the modified EPA Method 524.2.

Samples were collected in 300 mL BOD bottles for the UH-WRRC lab analysis. These samples were placed in the 4°C cold room until extraction was carried out. During extraction, the samples were poured into the 40 mL EPA sample vials (preserved with HCl) for BC Lab analysis. Each sample was poured into two BC vials to provide duplicates and enhance accuracy of test. The vials were supplied by BC Labs. In addition to the tested samples, a travel blank (deionized water) and field blank (influent water indirectly from water source) were collected and analyzed in both labs.

Samples were analyzed for TCP. EPA Standard Methods were used. TCP was analyzed by laboratory methods with a detection limit for EPA Method 524.2 of 5 parts per million (ppt). A brief overview of EPA Method 524.2 is provided in **section 3.5**.

UH-WRRC quality control included 10% duplicates and 10% continuing calibration verification.   After the initial RSSCT, the need to duplicate the samples to BC Laboratories was re-evaluated. It was decide that samples would continue to have duplicates.

3.3 **Determination of RSSCT Flow Rate**

The governing equations mentioned earlier in **section 2.3.2** were the basics of calculating most RSSCT flow rates.

$$\frac{EBCT_{sc}}{EBCT_{lc}} = \left(\frac{R_{sc}}{R_{lc}}\right)^2 = \frac{t_{sc}}{t_{lc}} \tag{5}$$

$$\frac{V_{sc}}{V_{lc}} = \frac{R_{lc}}{R_{sc}} \tag{8}$$

In this study, however, because the RSSCT column depth was purposely set at 2.00 cm, **equation 8** was not applicable. In order to simplify the study, all RSSCT runs #2 - 10 used the same column depth. However, forcing all of columns to have the same depth meant that proportions were inconsistent, leading to different full-scale and small-scale Reynold's numbers, thus rendering **equation 8** invalid.

Other fundamental fluid mechanics and environmental engineering equations were used. They are shown in **appendix 7.1**.

The first step was to collect all the known parameters for the full-scale model and small-scale model. For the full-scale model, the only known parameters were the GAC weight (W_{LC}), GAC specific gravity (SG_{LC}), flow rate (Q_{LC}), column diameter (CD_{LC}), and US. Sieve No. through which the GAC was sieved. Using these parameters, the column sectional area (A_{LC}), column volume (Vol_{LC}), column depth (L_{LC}), velocity, $EBCT_{LC}$, bed-volumes treated, and average GAC particle sizes were calculated.

For the small-scale model, the only known parameters were the column diameter (CD_{SC}), GAC specific gravity (SG_{SC}), and column depth (L_{SC}). Using these parameters, the column sectional area (A_{SC}), velocity (V_{SC}), column volume (Vol_{SC}), $EBCT_{SC}$, bed-volumes treated, GAC mass (m_{SC}), average GAC particle sizes, and flow rate (Q_{SC}) were calculated. The step-by-step calculations are shown in **appendix 7.1**

The goal of scaling the columns was to determine the small-scale (RSSCT) flow rates for each GAC size.

3.4 **GAC Properties**

The properties of both small-scale and full-scale models are shown below in **Table 3**. Calculations for the column sizing calculations are shown in **Appendix 7.1**.

Due to a miscommunication between the Primary Investigator and Graduate Assistant, an earlier version's (v3) flow rates were used for several GACs at the Kunia I well source and all GACs at the Waipahu III well source. All six GACs were tested with version 5's (v5) flow rates for each water source.

Table 3: Full and Small Scale GAC Properties (v5)

	Full - Scale			Small - Scale		
Carbon ID	A/B, F, G	D, E	C	A/B, F, G	D, E	C
Mesh Size US Sieve No.	12x40 (1.68 mm x 0.42 mm)	12x30 (1.68 mm x 0.595 mm)	8x30 (2.38 mm x 0.595 mm)	170x200 (0.088 mm x 0.075 mm)	170x200 (0.088 mm x 0.075 mm)	170x200 (0.088 mm x 0.075 mm)
GAC Avg. Particle Size	1.00 mm	1.14 mm	1.49 mm	0.082 mm	0.082 mm	0.082 mm
Flow Rate v5	$3785\ m^3/d$			5.10 mL/min	6.63 mL/min	11.32 mL/min
Flow Rate v3	$3785\ m^3/d$			4.35 mL/min	5.66 mL/min	9.67 mL/min
Column Diameter	3.66 m			4.76 mm		
Column Depth	2.59 m			2.00 cm		
Column Volume	$27.2\ m^3$			0.355 mL		
EBCT	10.355 min			0.070 min	0.054 min	0.031 min
Fill Weight	30000 lbs			0.178 g		

3.4.1 RSSCT Test Apparatus

The following equipment and materials were needed to assemble the RSSCT test apparatus:

- Small-Scale GAC Columns (4)
- 100-mesh stainless screen filters (2 per column, total 8)
- Neoprene O-rings (2 per column, total 8)

- Metal threads (2 per column, 8 total)
- PTFE Teflon tape
- Liquid metering pumps with flow rate indicator (4)
- Pressure gauges (4)
- Metal ring stand
- Water sample collection BOD bottles (1 per sample)
- Thin transparent tubing (size not specified)
- Oven
- Refrigerator (set at 10˚ C)
- Extraction Set – Up
- Effluent Containers (6)
- Analytical Balance
- Data Log Book

A photograph of the actual RSSCT test apparatus is shown in **Figure 13**.

Figure 13: Actual RSSCT Test Apparatus

Each component of the test apparatus is described in the following figures.

1. Small-Scale GAC Columns – The columns, shown in **Figure 14,** has a GAC column bed of 4.76 mm diameter x 2.00 cm deep column bed. **Figure 15** shows a loaded GAC column actively in use.

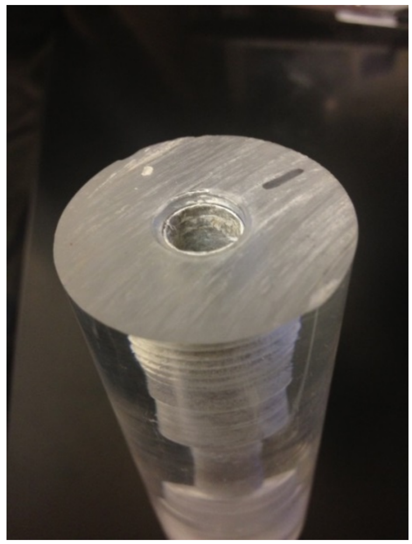


Figure 14: Small Scale GAC Column

Figure 15: GAC Column During a Run

2. GAC Supports – Metal threads are used to provide a sealed connection between the tubing and the glass column. Prior to twisting the metal thread into the column, a 100-mesh stainless screen is placed into the column to prevent GAC from leaking out, and PTFE (Teflon tape) is wrapped around the metal threads and a neoprene O-ring is placed into the column to provide a further water seal. Metal threads are shown below in **Figure 16**.

Figure 16: Metal Threads

3. Liquid Metering Pumps – A pump capable of maintaining a steady flow rate of ±0.05 mL/min at a column back pressure up to 100 psi was used. The pump has a bypass loop to allow the flow from the pump to recirculate to the pump inlet to relief pressure caused in the pump system. The pressure and water flow rate should be monitored and recorded in the data log book at each sample collection. **Figure 17** shows the water pumps.

Figure 17: Liquid Metering Pumps

4. Pressure Gauges – Pressure gauges were used to monitor the pressure in each system. They were attached to the tubing between the water pump outlet and the GAC column inlet. **Figure 18** below shows the pressure gauge used in this test.

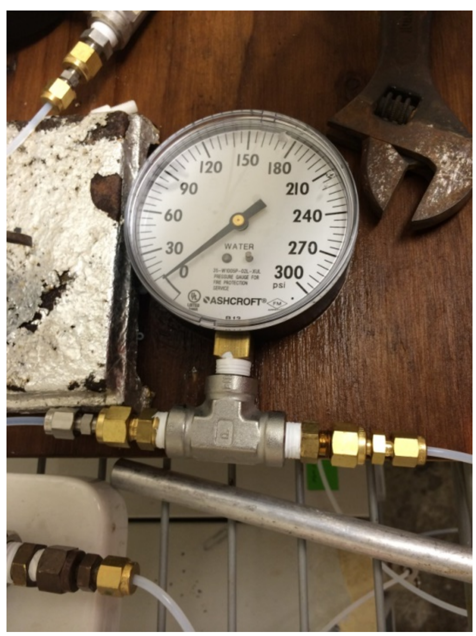


Figure 18: Pressure Gauge

5. Water Filtration – Water filtration was not used in the experiment.

6. Water Containment – The water being treated should be held at the same constant temperature as the GAC columns. The plastic containers containing the well water were held in a refrigerator at 10˚C. Tubing connected to the water pumps were inserted into the plastic container to pump the water out. Holes were cut in the refrigerator openings to provide space for the tube to enter the refrigerator. Plastic funnels were used to assist in the pouring of water into the containers. Since TCP is a volatile organic compound (VOC), it was important that all water containers containing the influent water be properly capped. During the pumping from the water container, however, the tube used to deliver water obstructed appropriate capping of the container. The container was therefore capped in such a way as to minimize the exposure of the water to the outside air as shown below in **Figure 19**.

Figure 19: Water Containers

7. Sample Collection System –300 mL BOD bottles were used to collect effluent water samples on a timely basis with zero head-space. The collected samples were stored in a refrigerated area to preserve the integrity of the sample. Samples can be collected in 35 mL vials up to 2 L water containers depending on the type of analysis performed. It should be noted that low flow rates and large water sample containers will contribute to sampling collection over an extended period of time. Error! Reference source not found. shows the BOD bottles used for water sample collection.

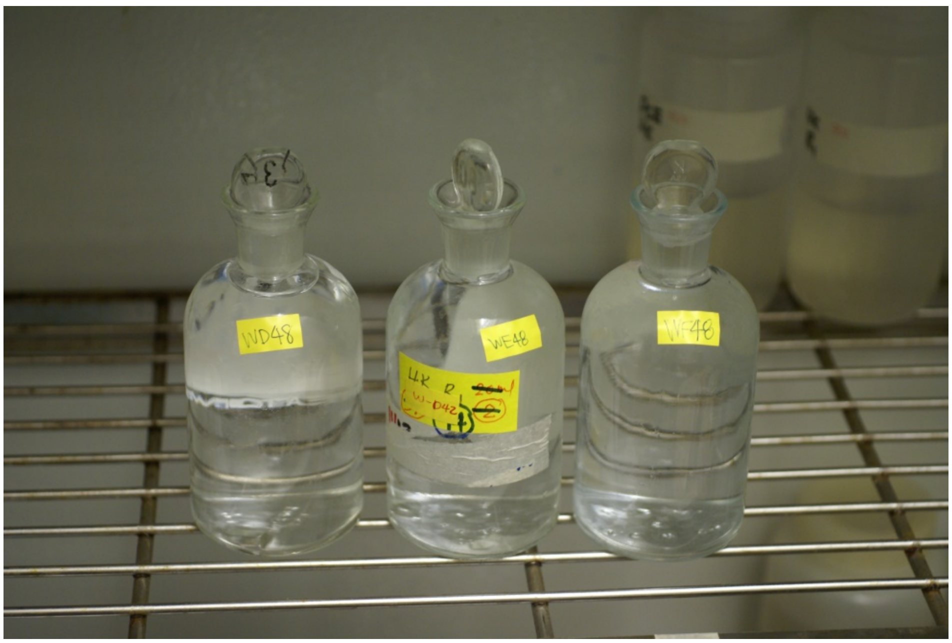


Figure 20: Effluent Water Samples

8. Sample Analysis – Auto-sampler vials were used to collect the extracted samples. These vials were subject to TCP analysis. When RSSCT was done for an extended period of time, the most recent samples were extracted and analyzed first in the reverse order from which it was sampled. Once several samples showed no breakthrough, the earlier samples did not need to be extracted and analyzed, thus saving time. **Figure 21** shows an auto-sampler vial.

Figure 21: Auto-sampler Vial

9. Drying Oven – An oven was used to dry the used and washed BOD sample collection bottles. Bottles were usually left in oven for at least 10 hours to ensure that they were adequately dried. Error! Reference source not found. shows the drying oven used.

Figure 22: Drying Oven

10. Refrigerator – The water containers in use were placed in a refrigerator to maintain a constant temperature. The refrigerator could store up to 8 water containers. **Figure 23** below shows the refrigerator used.

c

Figure 23: Refrigerator

11. Extraction Set -Up – Extraction of the contaminant (TCP) was a subsection of the RSSCT procedure. It was not specified in RSSCT how extraction should be

conducted. The extraction in this study was developed by the UH-WRRC staff to serve as an effective means of pulling out the contaminant from the water sample so that its concentration could be analyzed. The extraction set-up is shown in **Figure 24**.

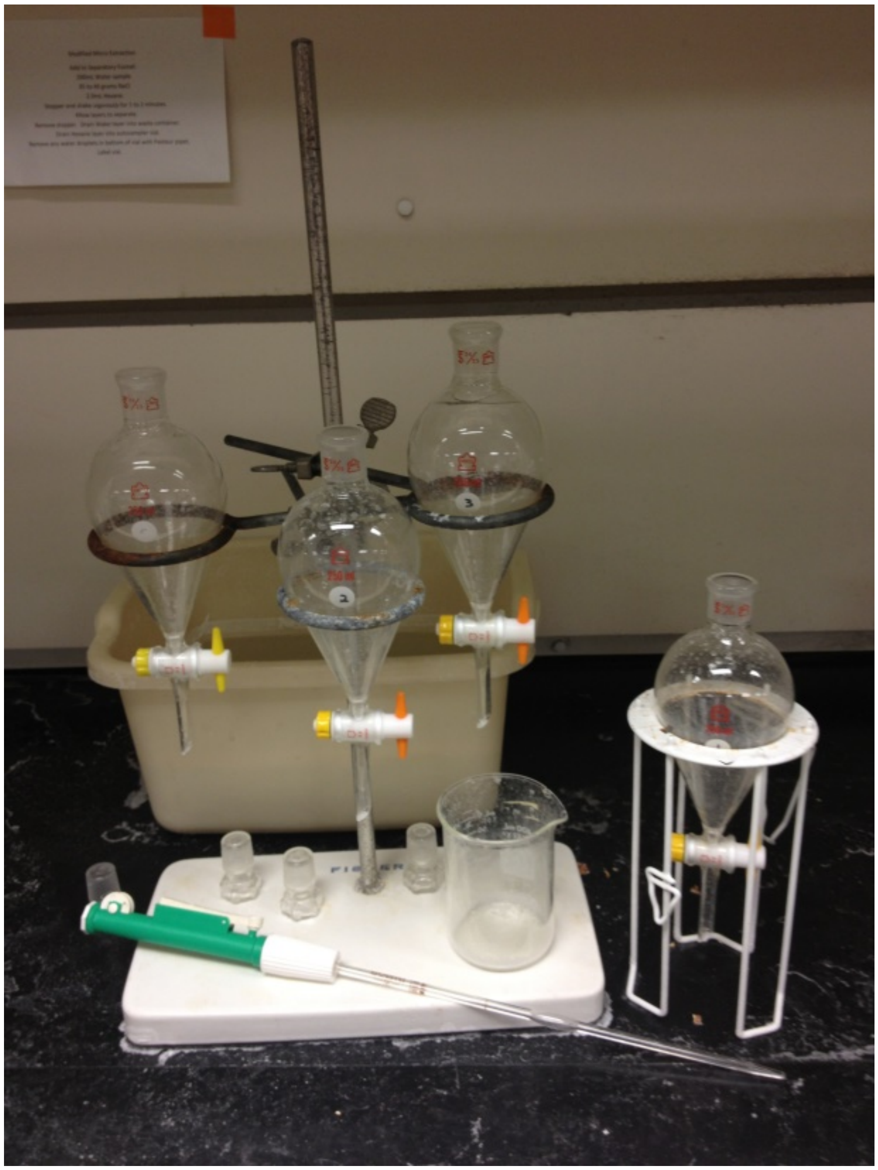


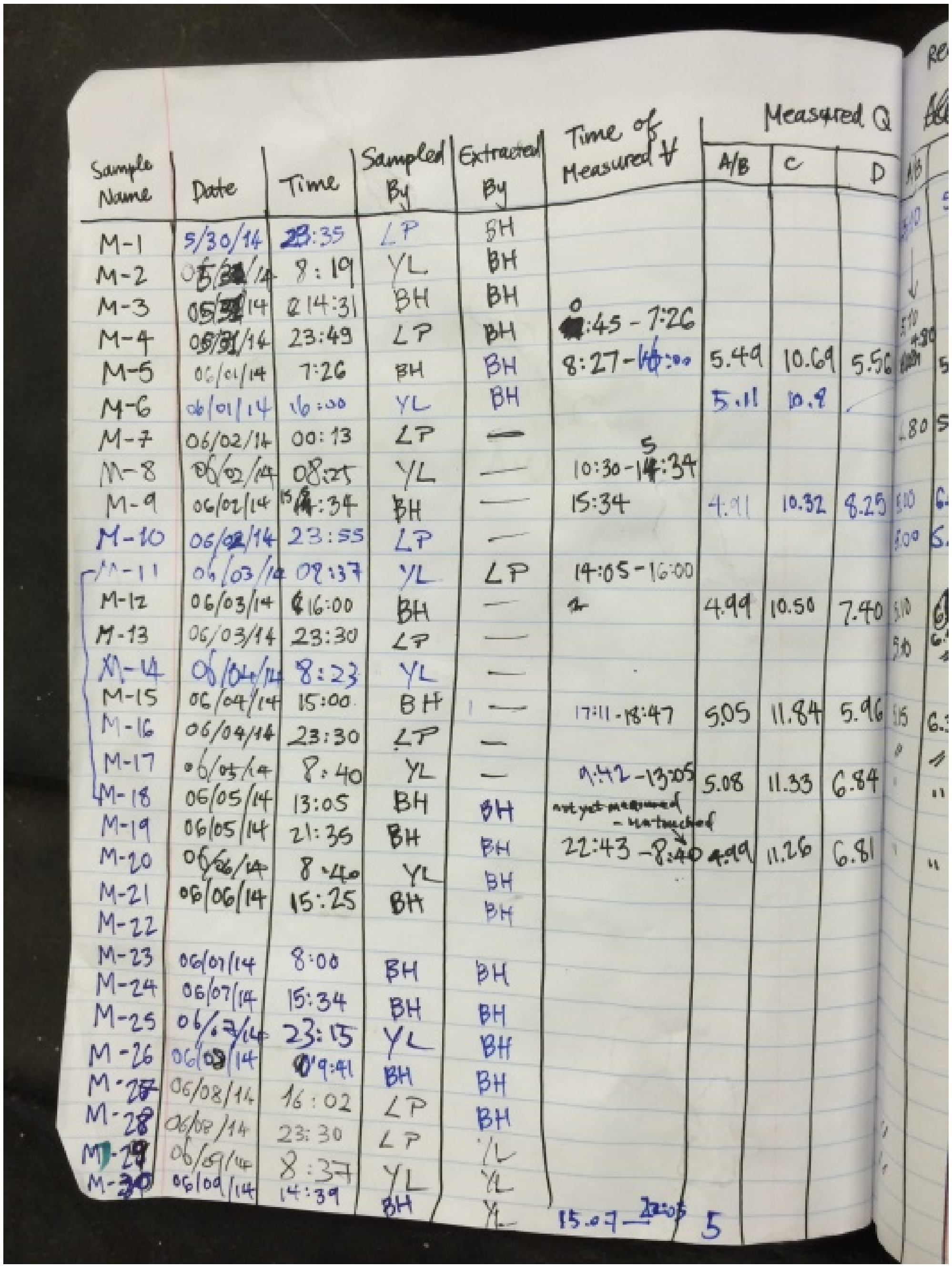
Figure 24: Extraction Set-Up

12. Effluent containers – Effluent containers were used to collect the effluent water in between sampling times. This effluent water was used to determine the actual flow rate in the system. The flow rates displayed on the water pumps

were slightly different from the actual; the water pumps flow rates were therefore adjusted according to the actual flow rate being discharged. **Figure 25** below shows each GAC's effluent water containers.

Figure 25: Effluent Containers

13. Data Log Book – A data log book was used to record the sample name, date, time, etc. for each sample. Proper and neatly recorded data was essential to the success of this study. The data log book is shown in **Figure 26**



Sample Name	Date	Time	Sampled By	Extracted By	Time of Measured V	Measured Q A/B	Measured Q C	Measured Q D
M-1	5/30/14	23:35	LP	BH				
M-2	05/31/14	8:19	YL	BH				
M-3	05/31/14	14:31	BH	BH				
M-4	05/31/14	23:49	LP	BH	0:45 - 7:26			
M-5	06/01/14	7:26	BH	BH	8:27 - 16:00	5.49	10.69	5.56
M-6	06/01/14	16:00	YL	BH		5.11	10.8	
M-7	06/02/14	00:13	LP	—				
M-8	06/02/14	08:25	YL	—	10:30 - 15:34			
M-9	06/02/14	15:34	BH	—	15:34	4.91	10.32	8.25
M-10	06/02/14	23:55	LP	—				
M-11	06/03/14	09:37	YL	LP	14:05 - 16:00			
M-12	06/03/14	16:00	BH	—		4.99	10.50	7.40
M-13	06/03/14	23:30	LP	—				
M-14	06/04/14	8:23	YL	—				
M-15	06/04/14	15:00	BH	—	17:11 - 18:47	5.05	11.84	5.96
M-16	06/04/14	23:30	LP	—				
M-17	06/05/14	8:40	YL	—	9:42 - 13:05	5.08	11.33	6.84
M-18	06/05/14	13:05	BH	BH	not yet measured - untouched			
M-19	06/05/14	21:35	BH	BH	22:43 - 8:40	4.99	11.26	6.81
M-20	06/06/14	8:40	YL	BH				
M-21	06/06/14	15:25	BH	BH				
M-22								
M-23	06/07/14	8:00	BH	BH				
M-24	06/07/14	15:34	BH	BH				
M-25	06/07/14	23:15	YL	BH				
M-26	06/08/14	9:41	BH	BH				
M-27	06/08/14	16:02	LP	BH				
M-28	06/08/14	23:30	LP	YL				
M-29	06/09/14	8:37	YL	YL				
M-30	06/09/14	14:39	BH	YL	15:07 - 22:05	5		

Figure 26: Data Log Book

3.4.2 Reagents

- Granular Activated Carbon (GAC)
- Well water source

3.4.3 Experimental Procedures

Since UH-WRRC lab only has four water pumps, only four GAC columns could be run at once. There are six GACs being tested; two runs, therefore, were required per well. After each completed run, the RSSCT equipment was dismantled, cleaned, and reassembled for the next run. Each run took approximately 2 weeks; it varied, however, between each GAC type and well sources. The higher the influent TCP concentration, the earlier the run was terminated. A run was only required to reach 10% of its influent TCP concentration (10% breakthrough) before termination. However, some GACs were stopped before 10% breakthrough because there was not enough time to reach this level without going over the scheduled end date of this project. Values for these occasions were interpolated. This should be taken into account when analyzing the data.

The experimental procedures that follow were formulated by the UH-WRRC staff.

3.4.4 GAC Grinding and Screening Procedure

A. Dry Sieve Portion

1. The granular activated carbon type to be ground was selected.
2. All carbon grinding was done under a fume hood. A 200 mL sample of selected GAC was ground using a grinder. Two types of grinders were used: a coffee grinder and a blender.
3. The GAC was ground for 10-15 seconds in the coffee grinder. After approximately 30 seconds, the GAC settled and the grinder could be removed.
4. A sieve-stack containing a pan, #200 sieves, #170 sieve, and cover was assembled. The parts were assembled from bottom to top in the precedent order.
5. The ground-up GAC was poured into the sieve-stack.

6. The sieve-stack was manually shaken for approximately 1 minute.
7. The GAC that had passed the #170 sieve but was retained by the #200 sieve was poured into a large Ziploc bag.
8. The sieve screens were tapped to make sure the screens were clean and no carbon remained to clog the sieve openings.
9. The GAC retained at #170 was poured back into the coffee grinder
10. Steps #3 - #9 were repeated two more times and poured into the same Ziploc bag. The ground-up GAC was then put through a wet sieve.

B. Wet Sieve Portion

1. Deionized (DI) water was poured into the Ziploc bag containing the dry sieved GAC.
2. The bag was shaken until all the GAC appeared to be wet.
3. The wet GAC was poured out of the bag and into a dry #200 sieve located over a sink.
4. Deionized water was poured and squirted onto the wet GAC until only a small amount of GAC was seen passing through the #200 sieve. This was checked by placing a white crucible under the sieve. Once the water was nearly all clear, the next step could be continued. However until this happened, this step was repeated.
5. The wet GAC was poured and squirted into a dry and clean crucible.
6. DI water was squirted into the crucible, mixing the water and GAC.
7. The DI water in the crucible was poured out into the sink along with the top floating GAC particles. The cleaned GAC was retained in the crucible.
8. Steps #16 - #17 were repeated until floating particles were negligible (5-10 times).
9. The GAC-containing crucible was labeled and placed in the oven until the crucible was dry.

C. GAC Column Loading and Set Up

1. The GAC Column was labeled according to the name of GAC placed in the column.
2. Two 100-mesh stainless screen filters were cut into circles the size of the column diameter openings. One filter was placed into the column opening.
3. A rubber O-ring was placed into the column opening onto the filter.
4. A metal thread was wrapped 5 times with Teflon tape.
5. A drop of distilled water was placed on the tip of the thread before it was screwed into the column. Thread was screwed in until it formed a snug fit to the O-ring.
6. Approximately 0.178 g of GAC was weighed on an analytical scale and poured into the column opening. Since all GACs are of different densities, the mass required to fill the entire column volume varied. It is important that the entire column volume be filled.
7. The other screen filter was placed in the open column opening onto the GAC bed.
8. Another rubber O-ring was placed into the open column opening onto the filter.
9. Another metal thread was wrapped 5 times with Teflon tape.
10. A drop of distilled water was placed on the tip of the thread before it was screwed into the column. Thread was screwed in until it formed a snug fit to the O-ring. This completed the GAC column loading.
11. The loaded GAC column was clamped to the metal ring stand shown in **Figure 13**.
12. Repeat steps #2 - #11 for each GAC being tested.

D. Column Testing Procedure

1. The tested water flows through the GAC apparatus via a thin Teflon tubing. This tubing starts in the water source, connects to the pumps, to the pressure gauge, to the GAC column, and out through the effluent tube end. Proper set up of this apparatus system is crucial to the accuracy of the test.

2. The tubing was cut into pieces suitable for each tubing connection.
3. Influent tubing was zip tied to a BOD bottle stopper and placed into the water container containing the influent water. The stopper was tied on the tubing to ensure the tube would sink to the bottom of the container even as water levels lowered. This tubing was attached to the pump entrance. Plastic fittings were used at each connection to make sure there was no leakage.
4. Tubing was connected between the pump exit to the pressure gauge entrance, from the pressure gauge exit to the column entrance, and from the column exit to an effluent waste container.
5. The apparatus was checked to ensure that there were no points of leakage.
6. The pump flow rate was set to the desired flow rate.
7. The pump was turned on.
8. The water samples were collected from the effluent tube in 300 mL BOD bottles until the water reached the neck of the BOD bottle. The sample number and starting time for each sample were recorded in the data log book. Bottles were capped, labeled, and placed into the cooling room until extractions were carried out. Bottles were capped with a stopper to ensure a water-tight seal. Bottles were labeled with the water source, carbon type, and sample number.
9. Effluent water was collected in the effluent containers and weighed between sampling intervals. The mass of water was converted to a volume and divided by the time to determine the actual pumping flow rate, Q_a. Q_a was recorded to determine the bed-volumes of water treated. Q_a was compared to the pumping rate shown on the pump, Q_p, and adjustments were made accordingly.
10. Water in actively used water containers were checked daily to ensure that the water levels did not run below ½ filled; if they were, they were filled with the stored water.
11. If any malfunction or error was found within the system, the pumps were stopped and their times and the malfunction descriptions were noted. Once the problem was solved, the pumps were started and their times were again noted.

3.5 EDB, DBCP, and TCP in Water by Microextraction and Gas Chromatography – EPA Method 504.1

TCP analysis was carried out in accordance with the Environmental Protection Agency (EPA) Method 504.1 – 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloro-propane (DBCP), and 1,2,3 – Trichloropropane (123TCP) in Water by Microextraction and Gas Chromatography (EPA 1995). A brief overview of EPA method 504.1's procedure, data analysis, and calculations are provided below.

3.5.1 Approach

This procedure is applicable for the determination of TCP in drinking water and groundwater (Henderson, Peyton et al. 1976, Richard and Junk 1977, Glaze and Lin 1984). Definite detection limits are highly variable on the Gas Chromatography (GC) used. Hexane was used as a solvent in the TCP extraction process. The 2-mL hexane extract (explained in **section 3.5.3**) was injected into the GC. This GC is equipped with a linearized electron capture detector able to separate and detect the amount of TCP. Extraction and analysis take approximately 30 – 50 minutes per sample. Evidence should be acquired for positive results.

3.5.2 Assumptions

The majority of analytical error will be attributed to impurities in the extracting solvent.

3.5.3 Procedure

Sample Preparation

1. Take samples and standards out from storage and allow them to reach room temperature before use.
2. For sample and field reagent blanks contained in 40 mL bottles, take off the cap and extract 5 mL of volume solution. Recap and weigh the bottle to the nearest 0.1 g. This will represent the gross weight, used in the subsequent sample volume equation (**equation 3**)

Extraction Procedure

1. Protective eye wear, a lab coat, gloves, and shoes were worn for this procedure.
2. Water samples stored in BOD bottles in the cold room were brought out to the lab bench.
3. Before extraction, each water sample was poured into two 40 mL BC lab vial containers. The vials were labeled with its corresponding water source, date and time, and sample number. These vials were given to AECOM, who then sent them to BC Laboratories to get the samples double checked for TCP analysis.
4. An important note for the extraction procedure is that all separatory funnels, graduated cylinders, and anything coming in contact with the water sample need to be washed thoroughly with deionized (DI) water in between samples to avoid cross contamination. Since there is only an incremental amount of TCP in each sample, any contamination will have a significant impact on the results.
5. The following items are added to the separatory funnel:
    a. 200 mL water sample
    b. 35 - 40 grams NaCl
    c. 2.0 mL Hexane
6. The separatory funnel was capped with a stopper and shaken vigorously for 1 - 2 minutes.
7. After 1- 2 minutes, layers in the funnel became separated. Two layers formed: a water layer and a hexane layer. The denser water layer will sit below the less dense hexane layer.
8. The stopper was removed and the water layer was drained into a waste container.
9. The hexane layer was drained through a pipette containing sodium sulfide into a 2- mL auto-sampler vial. The sodium sulfide was used to remove any residual water.
10. The auto-sampler vial was checked again for water. If water was present, it was extracted with a pipette.

11. Vials were labeled and analyzed for TCP using a gas chromatogram (GC). Any water in these vials could cause the GC machine to malfunction.

Determination of Sample Volume

1. For samples and field blanks, uncap and discard the remaining sample. Make sure all or as much as possible of the remaining water is removed.
2. Recap the empty container and weigh to the nearest 0.1 g. This represents the tare weight used in **equation 3**.

Data Analysis and Calculations

1. Calculate the sample volume (V_s)

$$V_s = gross\ weight - tare\ weight \tag{10}$$

2. Calculate the corrected sample concentration as:

$$Concentration\ (ppb) = C_i \times \frac{35}{V_s} \tag{11}$$

Where: C_i = uncorrected concentration (see EPA Method 504.1 for use of calibration curve)

For concentrations greater than 99 ppb, 3 significant figures were used; for concentrations from 1 - 99 ppb, 2 significant figures were used; and for less than 1 ppb, 1 significant figure was used.

4 RESULTS AND ANALYSIS

4.1 General

4.1.1 Results

The results of each of the GACs tested are shown in the following sections. The bed-volumes treated and TCP mass absorbed per GAC unit at the 1%, 5%, and 10% breakthrough points are displayed in separate tables. Along with the bed-volumes treated and TCP mass absorbed, these tables included the GAC type, water source, flow rate, version, and run number. The tables were color coded to make the results easier to interpret. **Table 4** indicates what each color means.

The breakthrough curves for each water source tested were plotted and are shown in the figures. The results by GAC type were plotted in relative concentration instead of effluent TCP concentration so that all water well sources with different influent TCP concentrations could be compared to one another. Influent TCP concentrations from each test run with their corresponding breakthrough TCP concentrations are shown in **Table 5**. The results by water well source are shown in effluent TCP concentration instead of relative concentration. Using the effluent TCP concentrations are very useful because the bed-volumes treated to reach a specific TCP concentration can be determined.

The results of each GAC were separated into subsections. First, it was categorized by GAC types as shown in **Section 4.2**. Each GAC type was tested with the three water sources. Next, the results are categorized by water well source as shown in **Section 4.4**. Each water well source had the six GAC types tested.

Waipahu III and Kunia I-wrong were plotted and shown in the tables; however, because they are not proportioned correctly, they were not used in the comparative analysis and not included in the averages. They were used only for a visual representation of how the GAC might behave at a slightly different flow rate. However, Kunia I-wrong and Waipahu III v3 can serve as good indicators to see if the breakthrough curves are following the correct trend. Kunia I-wrong uses a GAC F flow rate of 6.63 mL/min which is larger than the correct GAC F flow rate of 5.10 mL/min. Since everything else is left constant, an increase in flow rate will theoretically yield less bed-volumes treated at each breakthrough point. Waipahu III v3 has flow rates smaller than the correct v5 flow rates so it theoretically would yield more bed-volumes treated at each breakthrough point.

Table 4: Color Interpretation for Result Tables

Color	Meaning
Light Red	GAC Type
Yellowish Green	Parameters
Light Blue	Water Well Sources
Gray	Invalid Results
Light Orange	Breakthrough Limit Averages
Orange	Projected Values

Table 5: Influent TCP Concentration with Corresponding Breakthrough Limits

Influent TCP Concentration with Corresponding Breakthrough Limits (ppb)					
Run #	Water Source	Influent Concentration (ppb)	1% Breakthrough (ppb)	5% Breakthrough (ppb)	10% Breakthrough (ppb)
2	Kunia I	0.818	0.0082	0.0409	0.0818
3	Kunia I	0.794	0.0079	0.0397	0.0794
4	Waipahu III	0.554	0.0064	0.0321	0.0641
5	Waipahu III	0.554	0.0055	0.0277	0.0554
6	Mililani I	2.146	0.0215	0.1073	0.2146
7	Mililani I	2.298	0.0230	0.1149	0.2298
8	Kunia I	0.803	0.0080	0.0401	0.0803
9	Waipahu III	0.634	0.0063	0.0317	0.0634
10	Waipahu III	0.634	0.0063	0.0317	0.0634
11	Waipahu III	0.506	0.0051	0.0253	0.0506

4.1.2 Analysis

Theoretically, if the GAC type and flow rate remain constant and everything else remains the same, the TCP breakthrough curves should be identical. However, there are many variables to consider that can affect the accuracy of this test.

The initial 1% breakthrough is highly variable because the smallest indication of TCP concentration will be perceived as an initial breakthrough. However, a small contamination of the water sample from collection or extraction can be the cause of a false positive 1% breakthrough. A better indication of breakthrough is to measure the bed-volumes treated at 5% and 10% breakthrough.

Also, there are many other contaminants present in the groundwater tested. These contaminants such as natural organic matter (NOM) and other volatile organic compounds (VOC) can be present in groundwater at concentrations magnitudes larger than of TCP. These other contaminants bind to the GAC surface and can compete for adsorption sites on the GAC which can affect the GACs adsorption capacity for TCP. Only TCP was tested for in this study so it is unknown what other contaminants were present in the groundwater.

Also, two other main compounds, Dibromoethane (EDB) and 1,2-Dibromo-3-chloropropane (DBCP), which are usually tested for in drinking water were not tested in this study. The GAC effectiveness to these two other compounds may or may not follow the same trend as for TCP removal. The selection of the GAC type would normally depend on which is the most effective at removal of all hazardous compounds instead of one specific contaminant.

4.2 Results/Analysis by GAC Type

4.2.1 GAC A/B Results

Table 6: GAC A/B Breakthrough Results – Bed-Volumes Treated

GAC A/B – Bed-Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	3	161,229	196,004	219,659
Mililani I	5.10	v5	6	158,003	205,508	230,412
Waipahu III	5.10	v5	9	102,778	160,689	201,499
Waipahu III	4.35	v3	5	238,763	296,847	344,999
			Average	140,670	187,400	217,190

Table 7: GAC A/B Breakthrough Results – TCP Mass Adsorbed per GAC Unit

GAC A/B – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	3	3.48	4.20	4.67
Mililani I	5.10	v5	6	9.21	11.90	13.23
Waipahu III	5.10	v5	9	1.77	2.74	3.39
Waipahu III	4.35	v3	5	3.60	4.45	5.12
			Average	4.82	6.28	7.10

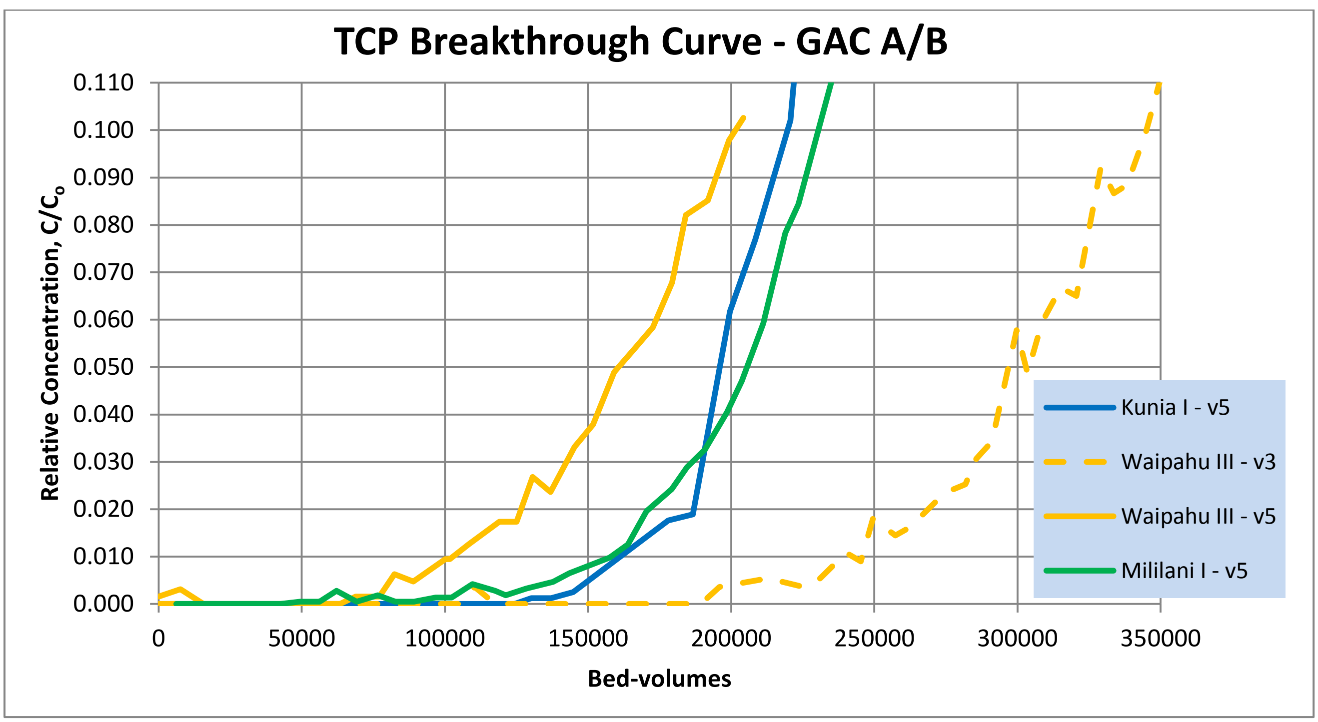


Figure 27: GAC A/B Breakthrough Results

4.2.2 GAC A/B Analysis

The breakthrough curve for GAC A/B, as shown in **Figure 27**, shows a similar breakthrough pattern in Kunia I and Mililani I waters. Waipahu III v5 treated less bed-volumes than Kunia I and Mililani I while Waipahu III v3 treated a lot more. The Waipahu III v3 breakthrough curve was approximately 50% greater than the other water sources at 1%, 5%, and 10% breakthrough. It would make sense that the Waipahu III water had a different breakthrough curve from the other water sources because the flow rate used for it was incorrect. The change from 5.10 to 4.35 mL/min would yield more treated bed-volumes compared to the others, but it would not lead to that drastic of an increase. Again all Waipahu III v3 results were not used in averages or GAC type comparisons. It was thought that the breakthrough curves for the different water well sources would be the same, but it was seen that Kunia I was not the same as the other two. This means that there must be something different amongst the different water sources that are affecting how the TCP is being adsorbed to the GAC. The water matrix of each water source must contain different concentrations of other contaminants.

As shown in **Table 6**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 140670, 187400, and 217190 respectively. As shown in

Table 7, TCP mass adsorbed was not the same for the different water sources. Mililani I water showed the most TCP adsorbed. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 4.82, 6.28, and 7.10 mg, respectively.

4.2.3 GAC C Results

Table 8: GAC C Breakthrough Results – Bed-Volumes Treated

GAC C – Bed-Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	11.32	v5	2	51,230	97,142	113,325
Mililani I	11.32	v5	6	26,395	71,843	103,852
Waipahu III	11.32	v5	10	35,212	67,711	91,732
Waipahu III	9.67	v3	5	65,147	109,268	128,116
			Average	37,612	78,899	102,969

Table 9: GAC C Breakthrough Results – TCP Mass Adsorbed per GAC Unit

GAC C – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	11.32	v5	2	0.49	0.93	1.07
Mililani I	11.32	v5	6	1.53	4.09	5.80
Waipahu III	11.32	v5	10	0.60	1.14	1.52
Waipahu III	9.67	v3	5	0.98	1.63	1.89
			Average	0.88	2.05	2.80

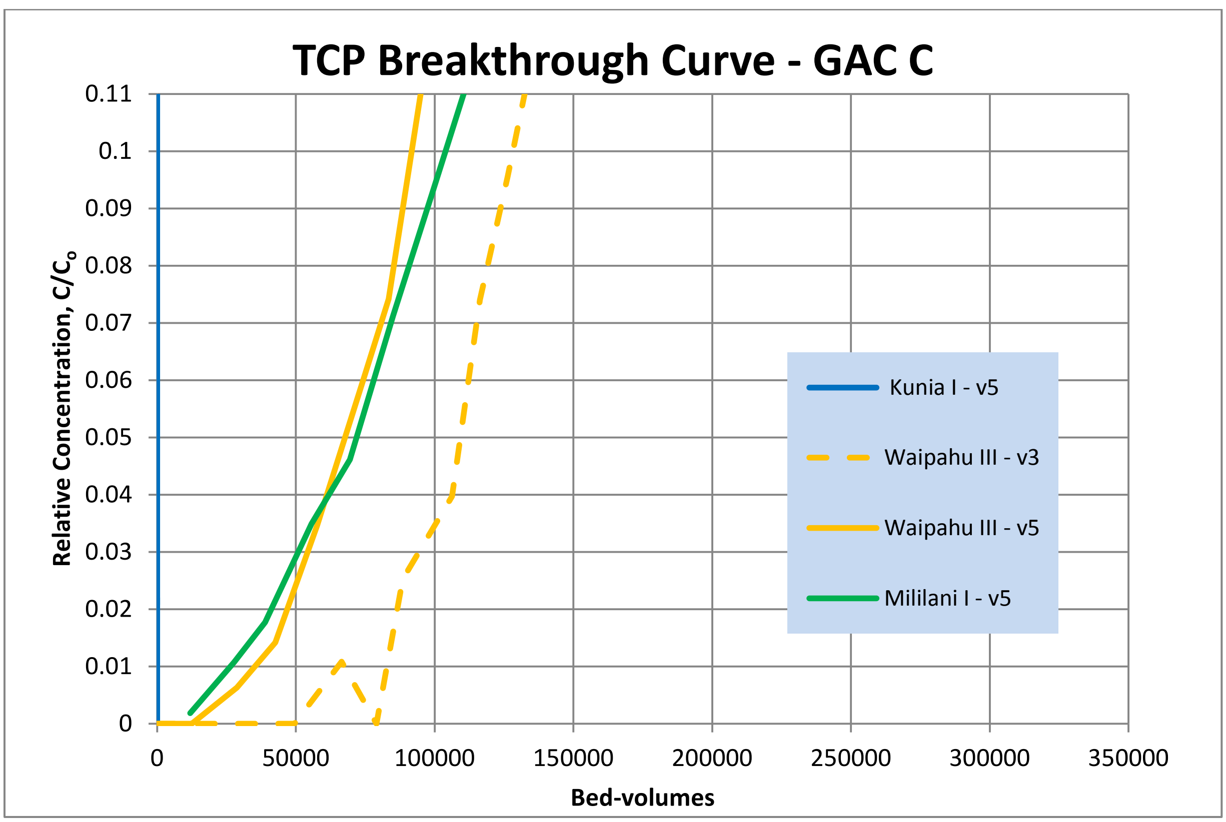


Figure 28: GAC C Breakthrough Results

4.2.4 GAC C Analysis

The breakthrough curve for GAC C, as shown in

Figure 28**,** shows a similar breakthrough pattern in all the waters tested. Waipahu III v5 and Mililani I showed nearly identical breakthrough curves, while Kunia I and Waipahu III v3 treated slightly more bed-volumes. The Mililani I water was the first to show an initial breakthrough (1% breakthrough) at 26395 bed-volumes while the Kunia I water was the last at 51230 bed-volumes. The 5% breakthroughs were relatively precise ranging from 67711 to 97142 bed-volumes. The 10% breakthroughs were also relatively precise ranging from 91732 to 113325 bed-volumes. GAC C, the current GAC used in Hawaii's water treatment facilities made of Jacobi direct-activated coal based carbon 8x30, was seen to treat the least bed-volumes at each breakthrough point. Their bed-volumes treated were substantially lower than the other GACs values. Because of this, consideration should be taken to replace it with another GAC.

As shown in **Table 8**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 37612, 78899, and 102696, respectively. As shown in

Table 7, TCP adsorbed was not the same for the different water sources. Mililani I water showed the most TCP adsorbed. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 0.88, 2.05, and 2.80 mg, respectively.

4.2.5 GAC D Results

Table 10: GAC D Breakthrough Results – Bed-Volumes Treated

GAC D – Bed-Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	6.63	v5	3	128,820	181,160	194,532
Kunia I	6.63	v5	8	164,224	214,707	245,779
Mililani I	6.63	v5	6	98,395	103,555	105,260
Waipahu III	6.63	v5	9	159,063	209,765	252,562
Waipahu III	5.66	v3	4	159,467	199,164	234,461
			Average	152,793	203,849	236,359

Table 11: GAC D Breakthrough Results – TCP Mass Adsorbed per GAC Unit

GAC D – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	6.63	v5	3	2.78	3.87	4.13
Kunia I	6.63	v5	8	3.51	4.58	5.20
Mililani I	6.63	v5	6	5.73	6.01	6.08
Waipahu III	6.63	v5	9	2.74	3.59	4.30
Waipahu III	5.66	v3	4	2.40	2.98	3.46
			Average	2.94	3.91	4.48

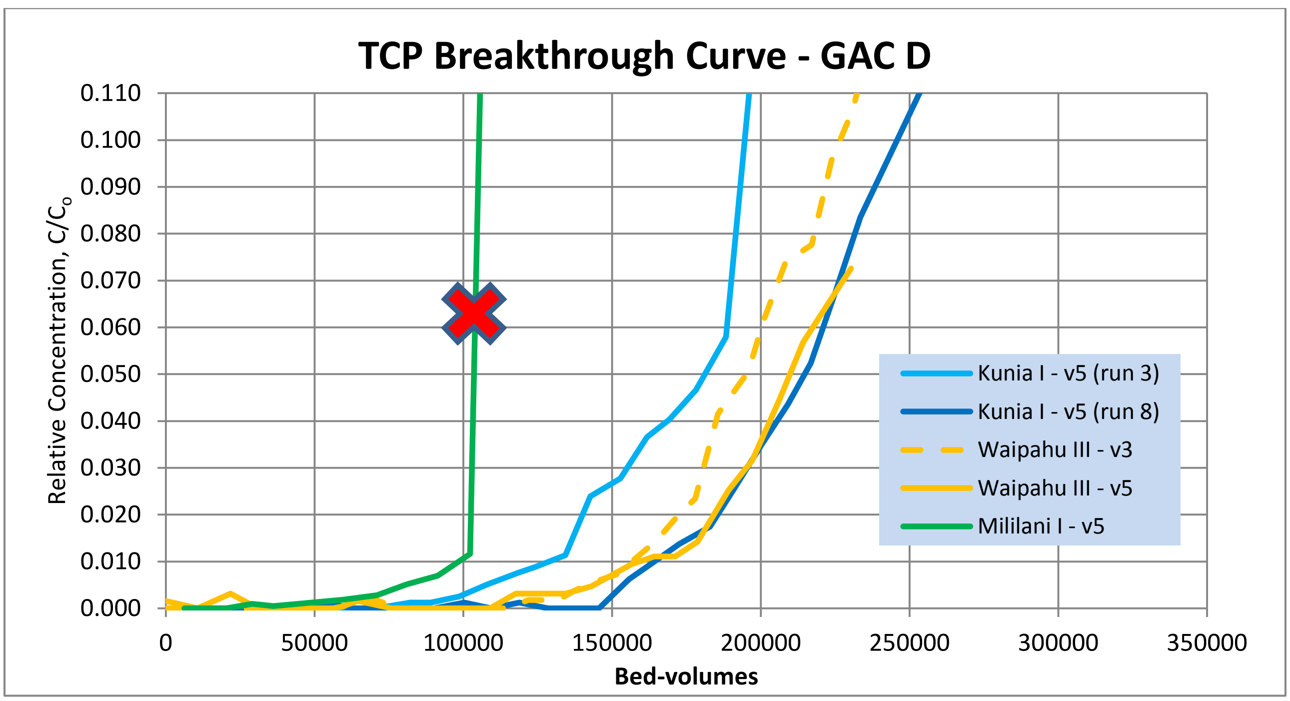


Figure 29: GAC D Breakthrough Results

4.2.6 GAC D Analysis

The breakthrough curves for GAC D, as shown in **Figure 29**, show a similar breakthrough pattern in all the waters tested except Mililani I and Kunia I – v5 (run 3). The Mililani I samples were subjected to a source of error. The TCP concentration in Mililani I samples jumped from 0.247 to 1.103 ppb (C/C_o equivalent jump of 0.115 to 0.514) over less than an 8 hour time span. These samples were inadvertently exposed to the air for about 10 hours, during which time it was highly possible that the TCP contaminant partially evaporated. It is highly unlikely that the TCP concentration would jump that drastically in such a small time interval. The Mililani I results were omitted from statistical analysis. The Kunia I samples were accidentally run twice at the exact same flow rate. This is the only GAC in the experiment that was rerun at the same flow rate. Theoretically, the breakthrough curves should be identical, but it can be seen that this is not the case. Kunia I – v5 (run #3) treated less bed-volumes at each breakthrough point when compared to run #8. The average of these two runs was used.

As shown in **Table 10**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 152793, 203849, and 236359, respectively. As shown in **Table 11**, TCP adsorbed was relatively similar for the two valid water sources. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 2.94, 3.91, and 4.48 mg, respectively.

4.2.7 GAC E Results

Table 12: GAC E Breakthrough Results – Bed-Volumes Treated

GAC E - Bed – Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	6.63	v5	3	64,960	108,739	134,780
Mililani I	6.63	v5	7	100,757	154,738	187,475
Waipahu III	6.63	v5	10	164,259	230,054	275,083
Waipahu III	5.66	v3	4	66,507	101,033	186,156
			Average	109,992	164510	199,113

Table 13: GAC E Breakthrough Results – TCP Mass Adsorbed per GAC Unit

GAC E – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	6.63	v5	3	1.40	2.32	2.84
Mililani I	6.63	v5	7	6.29	9.56	11.44
Waipahu III	6.63	v5	10	2.83	3.93	4.64
Waipahu III	5.66	v3	4	1.00	1.50	2.69
			Average	3.50	5.27	6.31

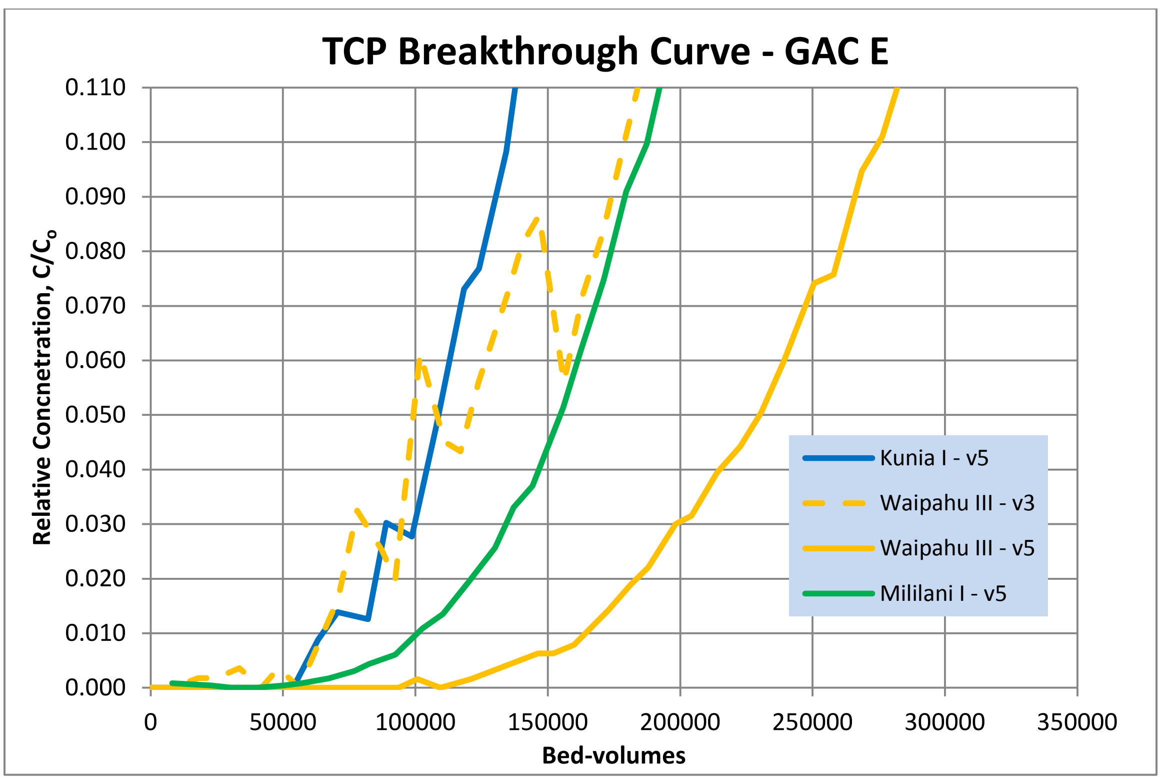


Figure 30: GAC E Breakthrough Results

4.2.8 GAC E Analysis

The breakthrough curves for GAC E, as shown in **Figure 30**, show breakthrough curves from each water well source that are all not very similar, with Waipahu III v5 treating a lot more bed-volumes than the rest. The Waipahu III v5 samples showed bed-volumes at each breakthrough limits that were over 50% greater than the next highest water source. The Kunia I and Waipahu III v3 breakthrough curves showed very similar 1% breakthroughs, however, once again, Waipahu III v3 cannot be used for in the analysis process. Therefore, Kunia I showed the lowest breakthrough values of the valid water samples for each of the 1%, 5%, and 10% breakthrough points.

As shown in **Table 12**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 109992, 164510, and 199113, respectively. As shown in **Table 13**, TCP mass adsorbed was not the same for the different water sources. Mililani I water showed the most TCP adsorbed. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 3.50, 5.27, and 6.31 mg, respectively.

4.2.9 GAC F Results

Table 14: GAC F Breakthrough Results – Bed-Volumes Treated

GAC F – Bed-Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	8	90,183	135,942	161,667
Kunia I	6.63	Wrong	3	56,787	106,151	137,539
Mililani I	5.10	v5	7	126,272	171,791	206,858
Waipahu III	5.10	v5	9	122,887	184,938	218,307
Waipahu III	4.35	v3	4	132,957	183,896	218,547
			Average	113,114	164,223	195,610

Table 15: GAC F Breakthrough Results – TCP Mass Adsorbed per GAC Unit

GAC F – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	8	1.96	2.93	3.45
Kunia I	6.63	Wrong	3	1.22	2.25	2.88
Mililani I	5.10	v5	7	7.88	10.65	12.63
Waipahu III	5.10	v5	9	2.11	3.16	3.68
Waipahu III	4.35	v3	4	2.00	2.74	3.21
			Average	3.99	5.58	6.59

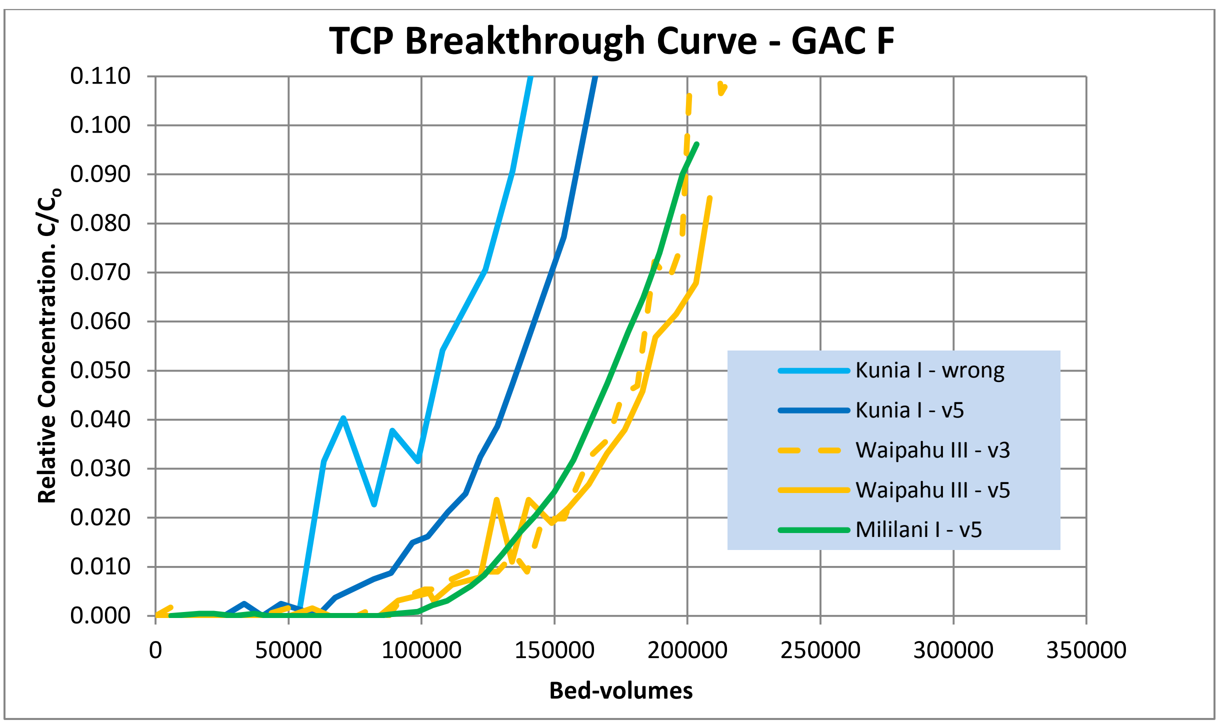


Figure 31: GAC F Breakthrough Results

4.2.10 GAC F Analysis

The breakthrough curves for GAC F, as shown in **Figure 31**, show nearly identical breakthrough curves in the Waipahu III v3, Waipahu III v5, and Mililani I sources. Both of the Kunia I wrong and v5 water treated less bed-volumes than the other three water sources. The Kunia I wrong water had breakthrough values smaller than the Kunia I v5 water which makes sense based on the statement in **section 4.1.1**. Again, Kunia I wrong and Waipahu III v3 breakthrough curves cannot be used.

As shown in **Table 14**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 113114, 164223, and 195610, respectively. As shown in **Table 15**, TCP mass adsorbed was similar for Kunia I and Waipahu II v5, but Mililani was higher than those. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 3.99, 5.58, and 6.59 mg, respectively.

4.2.11 GAC G Results

Table 16: GAC G Breakthrough Results – Bed-Volumes Treated

GAC G – Bed-Volumes Treated						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	8	55465	100,264	150,391
Mililani I	5.10	v5	7	121,200	170,807	197,542
Waipahu III	5.10	v5	10	164,259	230,054	275,083
Waipahu III	4.35	v3	5	174,595	219,551	258,980
			Average	113,641	170,375	207,674

Table 17: GAC G Breakthrough Results – TCP Adsorbed per GAC Mass

GAC G – TCP Mass Adsorbed per GAC Unit (mg)						
Well	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Kunia I	5.10	v5	8	1.20	2.15	3.17
Mililani I	5.10	v5	7	7.80	10.34	11.88
Waipahu III	5.10	v5	10	2.83	3.93	4.64
Waipahu III	4.35	v3	5	2.63	3.28	3.83
			Average	3.95	5.47	6.56

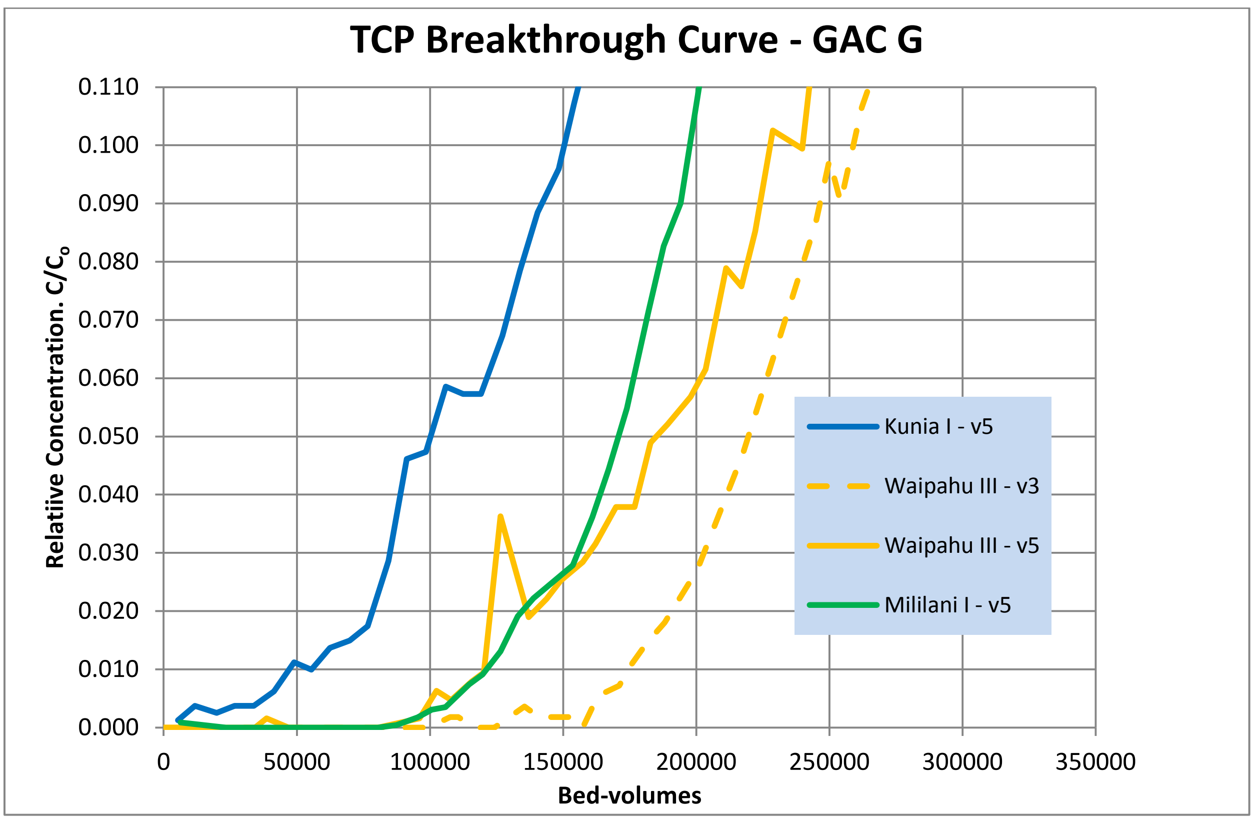


Figure 32: GAC G Breakthrough Results

4.2.12 GAC G Analysis

The breakthrough curves for GAC G, as shown in **Figure 32**, show different breakthrough curves for each water well source, with Kunia I treated a lot less bed-volumes. The 1% breakthroughs for each of the three water well sources were also different. Kunia I showed the earliest initial breakthrough at 55465 bed-volumes, Mililani I was in the middle at 121,200 bed-volumes and Waipahu III v5 showed the latest breakthrough at 164259 bed-volumes.

As shown in **Table 16**, the 1%, 5%, and 10% breakthrough average bed-volumes treated were 113641, 170375, and 207674, respectively. As shown in **Table 17**, TCP mass adsorbed was not the same for the different water sources. Once again, Mililani I water showed the most TCP adsorbed. The 1%, 5%, and 10% breakthrough average TCP adsorbed were 3.95, 5.47, and 6.56 mg, respectively.

4.3 Comparative Analysis – GAC Effectiveness based on Average Bed-Volumes Treated

Table 18: Average Bed-Volumes Treated

Comparison of GAC Averages – Bed-Volumes Treated				
Carbon Name	Flow Rate (mL/min)	1% Breakthrough (BV)	5% Breakthrough (BV)	10% Breakthrough (BV)
A/B	5.10	140,670	187,400	217,190
C	11.32	37,612	78,899	102,969
D	6.63	152,793	203,849	236,359
E	6.63	109,992	164,510	199,113
F	5.10	113,114	164,223	195,610
G	5.10	113,641	170,375	207,674

Table 19: Ranking GAC Effectiveness by GAC Type – Average Bed-Volumes Treated

Comparison of GAC Averages – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	D	D	D	**D**
#2	A/B	A/B	A/B	**A/B**
#3	G	G	G	**G**
#4	F	E	E	**E**
#5	E	F	F	**F**
#6	C	C	C	**C**

Table 20: Average TCP Mass Adsorbed per GAC Unit

Comparison of GAC Averages – TCP Mass Adsorbed per GAC Unit (mg)				
Carbon Name	Flow Rate (mL/min)	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	4.82	6.28	7.10
C	11.3	0.88	2.05	2.80
D	6.63	2.94	3.91	4.48
E	6.63	3.50	5.27	6.31
F	5.10	3.99	5.58	6.59
G	5.10	3.95	5.47	6.56

Table 21: Ranking Effectiveness by GAC Type – Average TCP Mass Adsorbed per GAC Unit

Comparison of GAC Averages – TCP Mass Adsorbed per GAC Unit (mg)				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	A/B	A/B	A/B	**A/B**
#2	F	F	F	**F**
#3	G	G	G	**G**
#4	E	E	E	**E**
#5	D	D	D	**D**
#6	C	C	C	**C**

The main objective of this study was to compare each of the six GACs to determine which one was the most effective at TCP removal. The breakthrough of the TCP contaminant was measured at 1%, 5%, and 10% breakthrough points. These breakthrough points will give a good indication of the TCP breakthrough for each of the

GACs. The bed-volumes treated at the breakthrough points are used to evaluate the effectiveness of the GACs. The more bed-volumes treated, the more effective the GAC.

The average bed-volumes treated for each GAC type and the ranking of the GAC effectiveness based on these averages are shown **Table 18** and **Table 19**. The averages excluded outliers. It can be seen that GAC D had the highest average bed-volumes treated for each of the breakthrough limits and GAC C had the lowest. These average bed-volumes treated, however, are not a very accurate measurement because the bed-volumes treated varies depending on the water well source. For a specific GAC, the breakthrough curves for each of the three water well sources were not identical. This means that there must be something different amongst the different water sources that are affecting how the TCP is being adsorbed to the GAC. The water matrix of each water well source must contain different concentrations of other contaminants. Also, because there was no trend, like one water well source always treating more bed-volumes, the different GAC types must not adsorb TCP in the same manner.

Therefore, it is not recommended to find a one-fits-all GAC to be applied for all of Hawaii's water treatment facilities, but rather to find a most effective GAC type specific to the water well source. A GAC type that is the most effective for one particular well could be the least effective for another well.

4.4 Results/Analysis by Water Well Source

4.4.1 Kunia I Results

Table 22: Kunia I Breakthrough Results – Bed-Volumes Treated

Kunia I – Bed-Volumes Treated						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	3	161,229	196,004	219,659
C	11.32	v5	2	51,230	97,142	113,325
D	6.63	v5	3	128,820	181,160	194,532
D	6.63	v5	8	164,224	214,707	245,779
E	6.63	v5	3	64,960	108,739	134,780
F	6.63	Wrong	3	56,787	106,151	137,539
F	5.10	v5	8	90,183	135,942	161,667
G	5.10	v5	8	130,546	100,264	150,391

Table 23: Kunia I – Effectiveness of GAC

Kunia I – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	A/B	D	D	D
#2	D	A/B	A/B	A/B
#3	F	F	F	F
#4	E	E	G	E
#5	G	G	E	G
#6	C	C	C	C

Table 24: Kunia I Breakthrough Results – TCP Mass Adsorbed per GAC Unit

Kunia I - TCP Mass Adsorbed per GAC Unit (mg)						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	3	3.48	4.20	4.67
C	11.32	v5	2	0.49	0.93	1.07
D	6.63	v5	3	2.78	3.87	4.13
D	6.63	v5	8	3.51	4.58	5.20
E	6.63	v5	3	1.40	2.32	2.84
F	6.63	Wrong	3	1.22	2.25	2.88
F	5.10	v5	8	1.96	2.93	3.45
G	5.10	v5	8	1.20	2.15	3.17

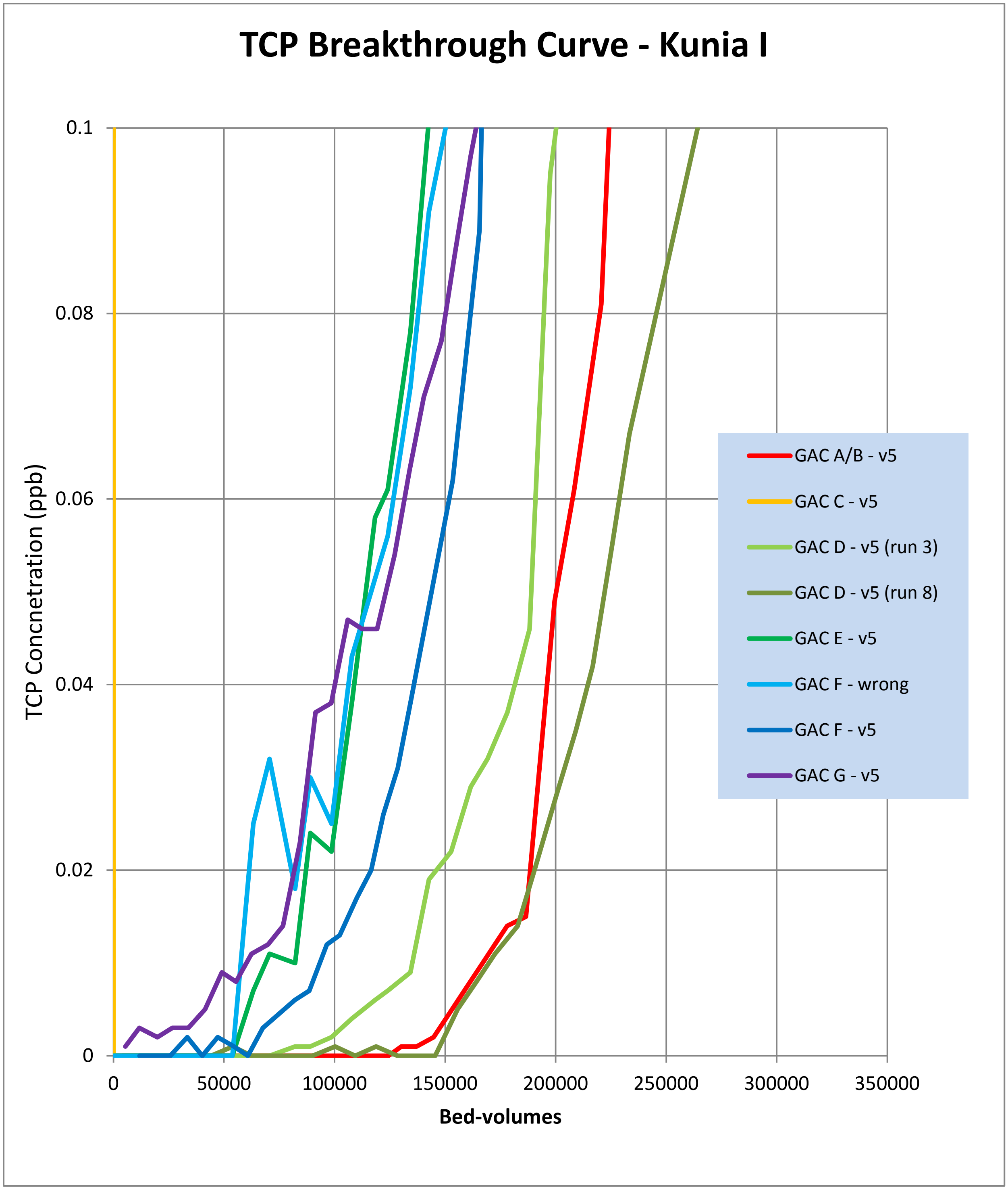


Figure 33: Kunia I Breakthrough Results

4.4.2 Kunia I Analysis

The breakthrough curves for Kunia I water, as shown in **Figure 33**, are shown for each GAC type. The bed-volumes treated, ranking of GAC effectiveness, and TCP adsorbed of each GAC type at each breakthrough point are shown in **Table 22, Table 23**, and **Table 24**, respectively. It is seen that GAC A/B and GAC D (both runs) showed the most bed-volumes treated at all breakthrough points. It is seen that of all the GAC types, GAC A/B treated the most bed-volumes at 1% breakthrough, while GAC D treated the most at 5% and 10% breakthrough. The difference between the bed-volumes treated between those two GACs was very close. GAC C treated the least bed-volumes at each breakthrough point.

GAC C, E, F (wrong), and G all showed relatively close initial breakthrough values at 50000 - 65000 bed-volumes. GAC E, F (wrong), and G showed very close patterns in the breakthrough curve, while GAC C deviated to a steeper slope as the TCP concentration increased. GAC F breakthrough curve was in between the low breakthrough curve bunch and GAC A/B and D curve bunch. The data from the TCP adsorbed was consistent with that of bed-volumes treated, as GAC A/B and D adsorbed the most and GAC C adsorbed the least.

Based on the Kunia I results, GAC A/B and GAC D were the most effective and GAC C was the least effective.

4.4.3 Waipahu III v3 Results

Table 25: Waipahu III v3 Breakthrough Results – Bed-Volumes Treated

Waipahu III v3 – Bed-Volumes Treated						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	4.35	v3	5	238,763	296,847	344,999
C	9.67	v3	5	65,147	109,268	128,116
D	5.66	v3	4	159,467	199,164	234,461
E	5.66	v3	4	66,507	101,033	186,156
F	4.35	v3	4	132,957	183,896	218,547
G	4.35	v3	5	174,595	219,551	258,980

Table 26: Waipahu III v3 – Effectiveness of GAC

Waipahu III v3 – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	A/B	A/B	A/B	A/B
#2	G	G	G	G
#3	D	D	D	D
#4	F	F	F	F
#5	E	C	E	E
#6	C	E	C	C

Table 27: Waipahu III v3 Breakthrough Results – TCP Mass Adsorbed per GAC Unit

Waipahu III v3 – TCP Mass Adsorbed per GAC Unit (mg)						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	4.35	v3	5	3.60	4.45	5.12
C	9.67	v3	5	0.98	1.63	1.89
D	5.66	v3	4	2.40	2.98	3.46
E	5.66	v3	4	1.00	1.50	2.69
F	4.35	v3	4	2.00	2.74	3.21
G	4.35	v3	5	2.63	3.28	3.83

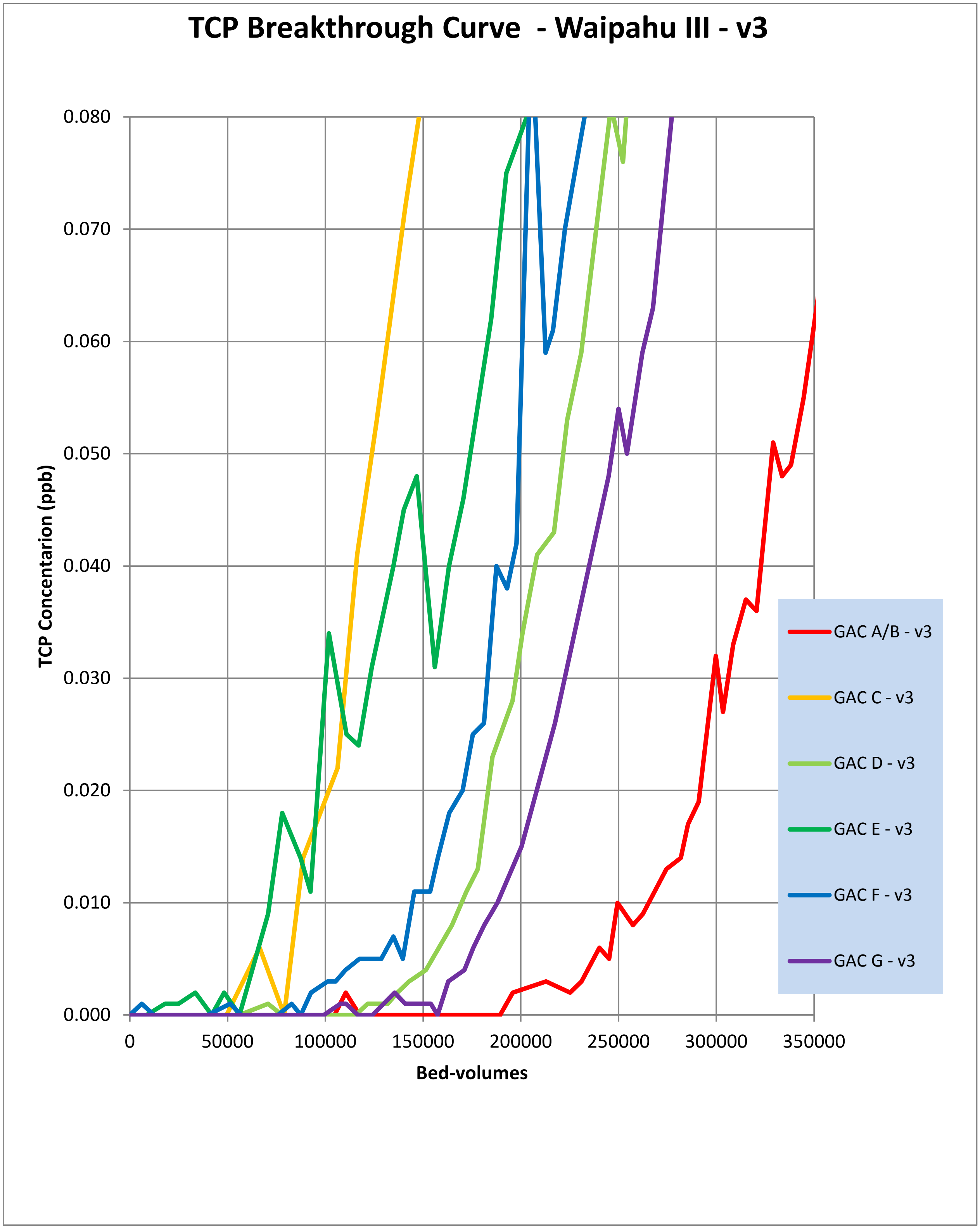


Figure 34: Waipahu III v3 Breakthrough Results

4.4.4 Waipahu III v3 Analysis

The breakthrough curves for Waipahu III v5 water, as shown in **Figure 34**, are shown for each GAC type. The bed-volumes treated, ranking of GAC effectiveness, and TCP adsorbed of each GAC type at each breakthrough point are shown in **Table 25**, **Table 26**, and **Table 27**, respectively. It can be seen that GAC A/B treated substantially more bed-volumes and adsorbed more TCP at a given TCP concentration than any other GACs and thus was the most effective GAC for Waipahu III v3. The next most treated bed-volumes were GAC G, followed by GAC D, GAC F, GAC E, and GAC C. GAC C treated the least bed-volumes at 1% and 10% breakthrough, while GAC E treated the least at 5% breakthrough. Overall, GAC C was the least effective. GAC A/B's 1%, 5%, and 10% breakthrough bed-volumes treated were 238763, 296847, and 344999, respectively which were substantially more than any other GAC type and water well sources combination tested in the experiment. GAC G, GAC D, and GAC F showed similar breakthrough values to each other as can be seen in **Table 25**. GAC C and E showed the earliest initial breakthroughs at 65147 and 66507 bed-volumes respectively. GAC C showed a smoother and steeper curve than GAC E. The jumps in concentrations in GAC E were most likely due to human error. The different types of errors found in this study are explained in **section 4.7**. The data from the TCP adsorbed was consistent with that of bed-volumes treated, as GAC A/B adsorbed the most and GAC C adsorbed the least.

No conclusions were based off of Waipahu III v3 results.

4.4.5 Waipahu III v5 Results

Table 28: Waipahu III v5 Breakthrough Results – Bed-Volumes Treated

Waipahu III v5 – Bed-Volumes Treated						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	9	102,778	160,689	201,499
C	11.32	v5	10	35,212	67,711	91,732
D	6.63	v5	9	159,063	209,765	252,562
E	6.63	v5	10	164,259	230,054	275,083
F	5.10	v5	9	122,887	184,938	218,307
G	5.10	v5	10	164,259	230,054	275,083

Table 29: Waipahu III v5 – Effectiveness of GAC

Waipahu III v5 – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	E	E	E	E
#2	D	D	D	D
#3	F	F	F	F
#4	G	G	G	G
#5	A/B	A/B	A/B	A/B
#6	C	C	C	C

Table 30: Waipahu III v5 Breakthrough Results – TCP Mass Adsorbed per GAC Unit

Waipahu III v5 – TCP Mass Adsorbed per GAC Unit (mg)						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	9	1.77	2.74	3.39
C	11.32	v5	10	0.60	1.14	1.52
D	6.63	v5	9	2.74	3.59	4.30
E	6.63	v5	10	2.83	3.93	4.64
F	5.10	v5	9	2.11	3.16	3.68
G	5.10	v5	10	2.07	3.15	3.83

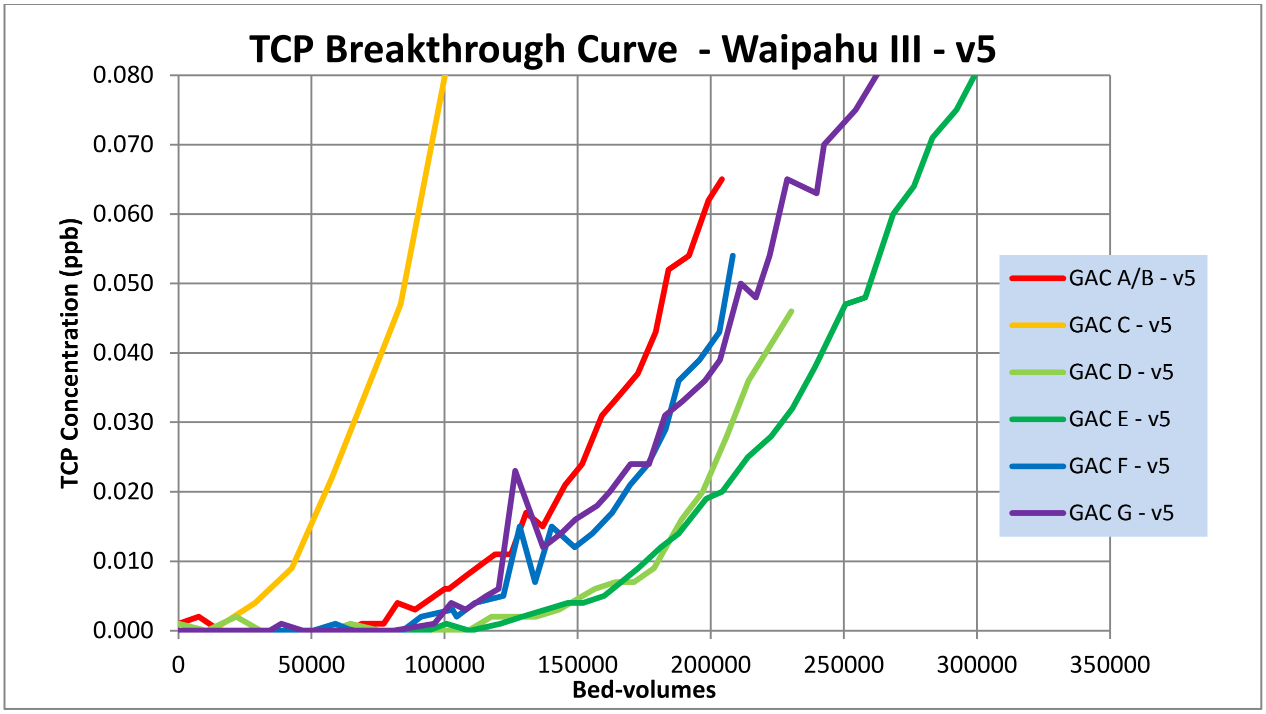


Figure 35: Waipahu III v5 Breakthrough Results

4.4.6 Waipahu III v5 Analysis

The breakthrough curves for Waipahu III v5 water, as shown in **Figure 35**, are shown for each GAC type. The bed-volumes treated, ranking of GAC effectiveness, and TCP adsorbed of each GAC type at each breakthrough point are shown in **Table 28**, **Table 29**, and **Table 30,** respectively. It can be seen that GAC E treated the most bed-volumes at each breakthrough point. This was followed by GAC D, then GAC F and GAC G which showed nearly identical values, followed by GAC A/B, and GAC C. All the GACs breakthrough curves were relatively close to each other except for GAC C. GAC C treated the least bed-volumes at each breakthrough point. The data from the TCP adsorbed was consistent with that of bed-volumes treated, as GAC E adsorbed the most and GAC C adsorbed the least.

Based on Waipahu III v5 results, GAC E was the most effective and GAC C was the least effective.

4.4.7 Mililani I Results

Table 31: Mililani I Breakthrough Results – Bed-Volumes Treated

Mililani I – Bed-Volumes Treated						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	6	158,003	205,508	230,412
C	11.32	v5	6	26,395	71,843	103,852
D	6.63	v5	6	98,395	103,555	105,260
E	6.63	v5	7	100,757	154,738	187,475
F	5.10	v5	7	126,272	171,791	206,858
G	5.10	v5	7	121,200	170,807	197,542

Table 32: Mililani I – Effectiveness of GAC

Mililani I – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	A/B	A/B	A/B	A/B
#2	F	F	F	F
#3	G	G	G	G
#4	E	E	E	E
#5	C	C	C	C

Note: GAC D was omitted due to an experimental error

Table 33: Mililani I Breakthrough Results – TCP Mass Adsorbed per GAC Unit

Mililani I – TCP Mass Adsorbed per GAC Unit (mg)						
Carbon Name	Flow Rate (mL/min)	Version	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
A/B	5.10	v5	6	9.21	11.90	13.23
C	11.32	v5	6	1.53	4.09	5.80
D	6.63	v5	6	5.73	6.01	6.08
E	6.63	v5	7	6.29	9.56	11.44
F	5.10	v5	7	7.88	10.65	12.63
G	5.10	v5	7	7.80	10.34	11.88

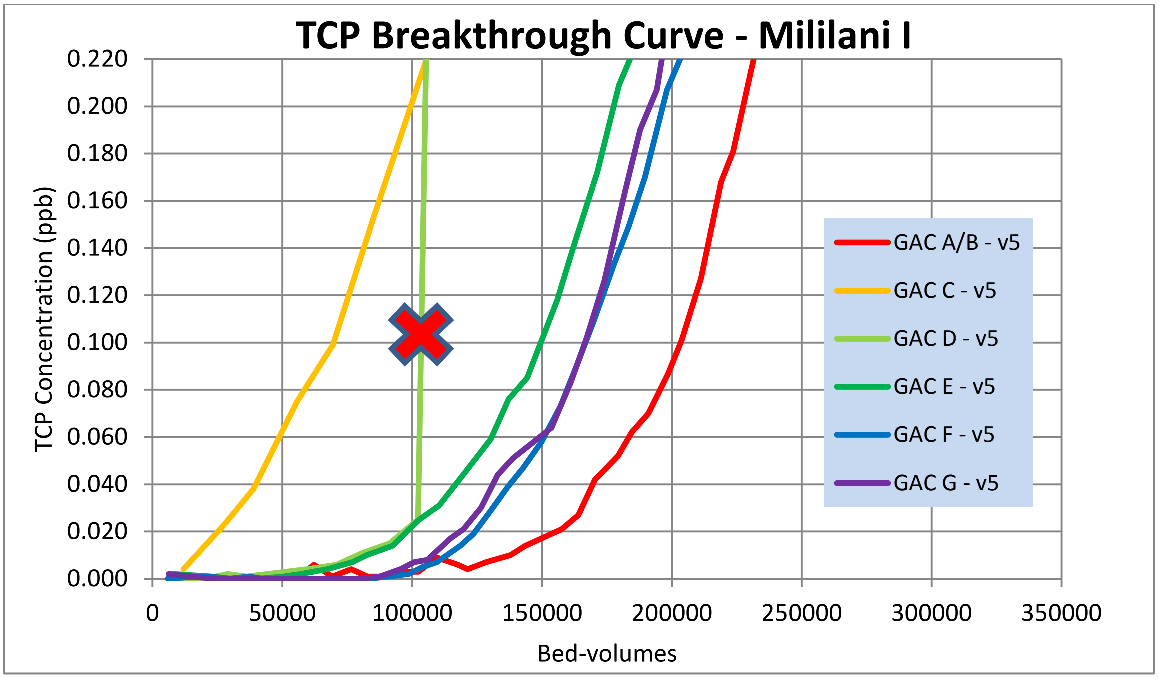


Figure 36: Mililani I Breakthrough Results

4.4.8 Mililani I Analysis

The breakthrough curves for Mililani I water, as shown in **Figure 36**, are shown for each GAC type. The bed-volumes treated, ranking of GAC effectiveness, and TCP adsorbed of each GAC type at each breakthrough point are shown in **Table 31**, **Table 32**, and **Table 33**, respectively. It can be seen that GAC A/B treated the most bed-volumes at each breakthrough point compared to the other GACs. The GAC with the next most treated bed-volumes was GAC F and G which showed nearly identical results, followed by GAC E, GAC D, and GAC C. GAC C treated the least bed-volumes at each breakthrough points. GAC C also had a 1% breakthrough of 26395 bed-volumes, the lowest of any GAC and water well source combination. The other GACs showed 1% breakthroughs ranging from 100757 to 158003 bed-volumes. GAC D's results were omitted due to the experimental error that was previously described. The data from the TCP adsorbed was consistent with that of bed-volumes treated, as GAC A/B adsorbed the most and GAC C adsorbed the least.

Based on Mililani I results, GAC A/B was the most effective and GAC C was the least effective.

4.5 Comparative Analysis – GAC Effectiveness by Water Well Site

Table 34: GAC Effectiveness by Water Well Site

Overall Rank	Kunia I	Waipahu III	Mililani I
#1	D	E	A/B
#2	A/B	D	F
#3	F	G	G
#4	E	F	E
#5	G	A/B	C
#6	C	C	

Table 35: Most and Least Effective GAC by Water Well SIte

Well	Most Effective		Least Effective
Kunia I	GAC D	GAC A/B	GAC C
Waipahu III	GAC E		GAC C
Mililani I	GAC A/B		GAC C

The effectiveness of the GAC type by each water well sources is shown in **Table 34** and **Table 35**. It can be seen that the least effective GAC for each water well site was GAC C. The most effective GAC was dependent on the water site. GAC D looked to be effective for Kunia I and Waipahu III, but because of the error in Mililani I, it is unknown how effective GAC D is for Mililani I. GAC A/B also was observed to be effective for Kunia I and Mililani I, but it was not for Waipahu III.

For Kunia I, GAC A/B and D were the most effective and GAC C was the least. For Waipahu III, GAC E was the most effective and GAC C was the least and for Mililani I, GAC A/B was the most effective and GAC C was the least. In all three water well sources tested, GAC C, the current GAC used, was the least effective GAC type.

4.6 Results/Analysis by GAC Particle Size

4.6.1 GAC Particle Size Results

Table 36: Properties of GAC Particle Size

Waipahu III GAC A/B			
	U.S. Mesh Size	Flow Rate	
Largest	100 x 120	3.42	mL/min
↑	120 x 140	4.07	mL/min
↓	140 x 170	4.82	mL/min
Smallest	170 x 200	5.74	mL/min
Bed Volume		0.355	mL
TCP Influent		0.506	ppb

Table 37: GAC Particle Size Breakthrough Results – Bed-Volumes Treated

Waipahu III GAC A/B – Bed-Volumes Treated					
Carbon Size	Flow Rate (mL/min)	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Limiting Concentration (ppb)			0.0051	0.0253	0.0506
100 x 120	3.42	11	344,371	462,863	538,015
120 x 140	4.07	11	276,376	355,973	409,157
140 x 170	4.82	11	260,776	340,779	384,473
170 x 200	5.74	11	192,564	236,700	274,239

Table 38: GAC Particle Size – Effectiveness

Kunia I – Bed-Volumes Treated				
Ranking	1% Breakthrough	5% Breakthrough	10% Breakthrough	Overall
#1	100 x 120	100 x 120	100 x 120	**100 x 120**
#2	120 x 140	120 x 140	120 x 140	**120 x 140**
#3	140 x 170	140 x 170	140 x 170	**140 x 170**
#4	170 x 200	170 x 200	170 x 200	**170 x 200**

Table 39: GAC Particle Size Breakthrough Results – TCP Mass Adsorbed per GAC Unit

Mililani I – TCP Mass Adsorbed per GAC Unit (mg)					
Carbon Name	Flow Rate (mL/min)	Run #	1% Breakthrough	5% Breakthrough	10% Breakthrough
Limiting Concentration (ppb)			0.0051	0.0253	0.0506
100 x 120	3.42	11	4.73	6.32	7.27
120 x 140	4.07	11	3.80	4.86	5.53
140 x 170	4.82	11	3.59	4.65	5.20
170 x 200	5.74	11	2.65	3.23	3.70

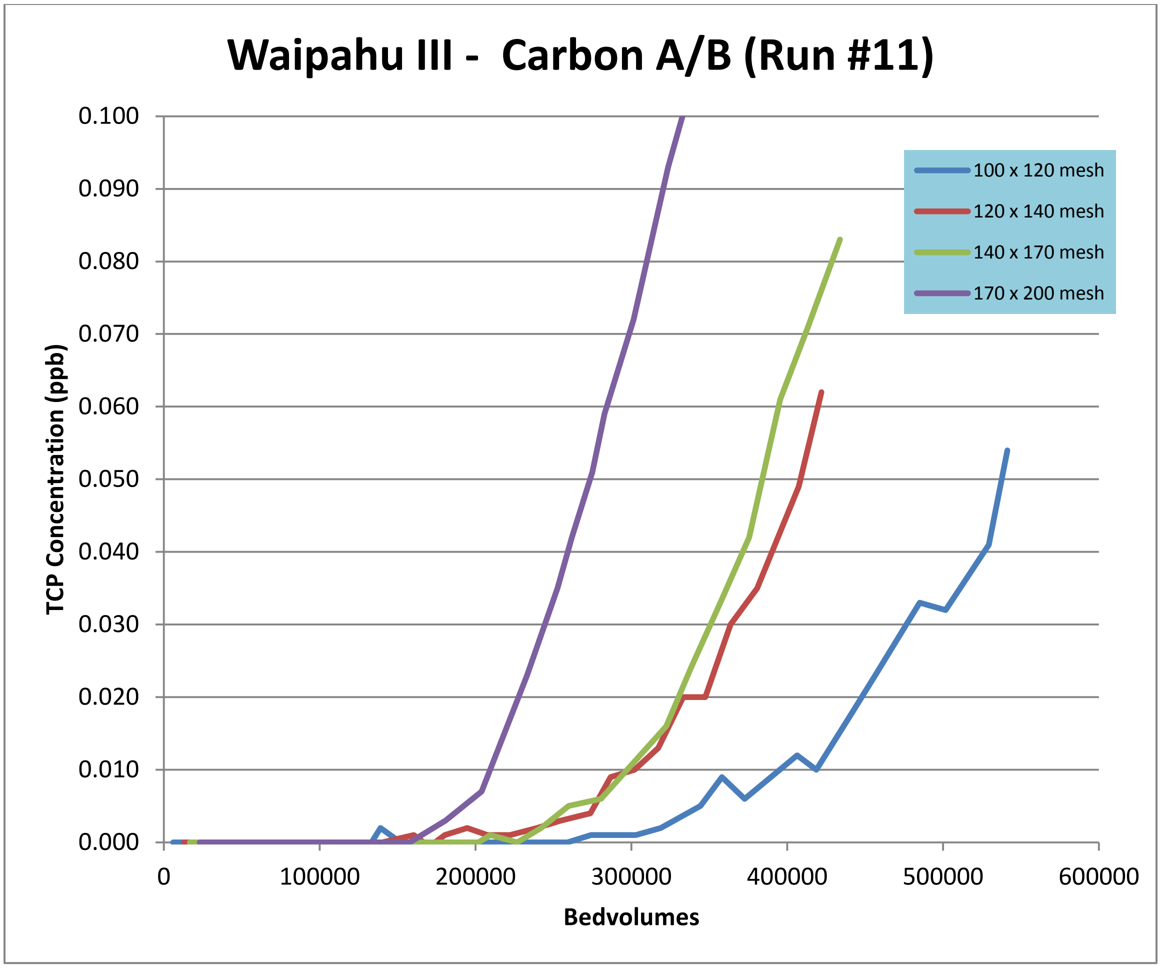


Figure 37: GAC Particle Size Breakthrough Results

4.6.2 Different GAC Particle Size Analysis

A comparative analysis was done to determine whether or not the GAC particle size had an effect on the breakthrough curve. The GAC type and water site was held constant. GAC A/B and Waipahu III water was selected for this study. Four different GAC particle sizes were tested against each other. The tested GACs are from largest to smallest GAC particles size; 100 x 120, 120 x 140, 140 x 170, and 170 x 200 mesh GACs. The small-scale flow rate and column depth were scaled proportionally so that, theoretically, the TCP breakthrough curves of each GAC particle size would be identical. More on the column scaling calculation are in **appendix 7.1**

The breakthrough curves for the GAC particle size study, as shown in **Figure 37**, are shown the different GAC particle sizes. The bed-volumes treated, ranking of GAC effectiveness, and TCP adsorbed of each GAC type at each breakthrough point are shown in **Table 37**, **Table 38**, and **Table 39**, respectively. It can be seen that GAC 100 x 120 mesh size treated the most bed-volumes at each breakthrough point compared to the other GACs. The GAC with the next most treated bed-volumes was GAC 120 x 140, 140 x 170, and 170 x 200 mesh size at each breakthrough point.

It is seen that the GAC particle size was related to the amount to reach its breakthrough points. The larger the GAC particle size (smaller mesh #), the more bed-volumes it took to reach its breakthrough limits. 170 x 200 mesh GAC broke through significantly earlier than the others. 120 x 140 and 140 x 170 mesh GACs had nearly identical breakthrough curves with a slight difference between the TCP concentrations of 0.020 - 0.030 ppb. 100 x 120 mesh GAC treated over 500000 bed-volumes before reaching a 10% breakthrough.

Based on the results, the theoretical concept that the breakthrough curve would be identical at different GAC particles sizes is not true. Even though the GAC was scaled correctly, the size of the particles made a difference in the breakthrough curve. It was seen that the smaller the GAC particle size, the less bed-volumes and less effective the GAC was. This was contrary to what was believed. If the breakthrough curves were not identical, it was thought that the smaller the GAC particle size, the more bed-volumes and more effective the GAC was because there would be more surface area per GAC pore volume. Since the results were like this, the accuracy of the RSSCT scaling equations has been questioned.

Another interesting finding from this study was that GAC A/B performed a lot better in this run than it did previously. Looking at the results, 170 x 200 mesh GAC A/B Waipahu III treated 192564, 236700, and 274239 bed-volumes at 1%, 5%, and 10% breakthrough while in the earlier run (run #9, p. 57), the same GAC treated 102778, 160689, and 201499 bed-volumes, respectively. If the latter run was the correct then GAC A/B would be the most effective for Waipahu III as well. This adds evidence to question the accuracy of the RSSCT scaling equations.

4.7 **Error**

Error has a significant impact on an experiment. There are many variations that can occur due to error. This is a list of possible sources of error in our research:

1. Different people working on the same task of the experiment: This is a huge source of error because different people will follow and perceive the same experimental procedure differently. For example, the GAC grinding, sieving, sampling, and TCP extractions were all done by multiple people. Small variations in a protocol and operator technique can yield significantly different results.
2. The flow rate reading on the water pumping meters were not accurate to $\pm$ 0.05 mL/min as previously mentioned. A manual calculation of dividing the treated effluent water volume by the elapsed time was used to find the actual flow rate. This flow rate was calculated between sampling times. Because of this, the flow rates were not very accurate or consistent, especially for the first several flow rates when the pumps were not calibrated to the right value.
3. The TCP extraction procedure used separatory funnels that are washed between different samples. Failure to wash out the funnels thoroughly could easily result in cross contamination.
4. The 2 mL of hexane that was measured during TCP extraction was measured by the human eye. Just an incremental change in hexane added to the sample could yield inaccurate results.
5. The 200 mL sample was measured in one graduated cylinder by the human eye. Besides measurement errors, there is also a chance for cross contamination.
6. The water containers holding the tested water were not capped with a seal. This was because the tube used to pump out the water interfered with capping. TCP could have evaporated in the water containers due to imperfect sealing.
7. Only the initial set of influent water in a run was tested for TCP concentration. This means if the influent TCP concentration varied at any given water well, the results would be inaccurate.

8. The GAC columns (runs #2 - 10) were filled based on the amount to completely fill the column volume. A more accurate method would be to weigh the GAC.

5 CONCLUSIONS

A granular activated carbon (GAC) water treatment study was conducted to evaluate six different types of GACs and determine their ability to absorb TCP, a hazardous chemical compound found in Hawaii's drinking water aquifers. The most effective GAC type would be recommended as a replacement for the currently used GAC unit in Hawaii's water treatment facilities. A time efficient and economical method called Rapid Small-Scale Column Test (RSSCT) was used to model a full-scale GAC unit from a bench-scale test using small-scale columns.

The key findings from this study were:

- Any of the 6 GACs tested can meet the possible new 5 ppt MCL for TCP. This was never known or tested for before in Hawaii. Analytical methods were able to detect TCP concentration = 1 ppt. This was previously not thought to be possible. This is a valuable finding. The State of Hawaii can lower its MCL to 5 ppt because all the tested GACs will be able to safely treat the TCP contaminated groundwater. The duration the GAC can be used; however, it varies by GAC type.
- GAC C, the GAC currently used in Hawaii's water treatment facilities, was the least effective GAC type in each of the three water well sources. It treated the least bed-volumes by far. This is insightful because, based on the water wells tested, any of the other GACs could replace the current one and be more effective. Although other water wells could fair differently, it is highly unlikely that GAC C would be the most effective GAC for any water source.
- There was no GAC that was the most effective for all three water sources; therefore, it is not necessary to find a one-fits-all GAC to be applied for all of Hawaii's water treatment facilities, but rather a most effective GAC type specific

to the water well source. A GAC type that is the most effective for one particular well could be the least effective for another well.

- The data suggests that the most effective GAC by water well source was:
    - Kunia I – GAC A/B and D
    - Waipahu III – GAC E
    - Mililani I – GAC A/B
- The GAC particle size affects the effectiveness of GAC for TCP removal. The smaller the GAC particle size, the less effective the GAC was. Even through the GAC was proportionally scaled correctly, the particle size made a difference in the breakthrough curve.
- The accuracy of the RSSCT scaling equations should be looked at in further detail.
- Only TCP was analyzed in this study, however, other contaminants are in the groundwater (natural organic matter, other volatile organic compounds, pesticides, etc.) and they affect the GAC's adsorption capacity for TCP.
- The GAC performance to effectively treat EDB and DBCP is important. It would be taken into consideration when the selection of the most effective GAC to treat Hawaii's groundwater is made.

The findings from this RSSCT study are of great value and significance. Replacing the currently used GAC unit with a more effective one means the units in the field would need to be changed less frequently, thus saving on maintenance and operating costs.

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7 APPENDIX

7.1 Column Sizing Calculations

7.1.1 Full-Scale Column Parameters (Given)

GAC Weight/Adsorber, W_{LC}	30,000	lb
GAC Specific Gravity, SG_{LC}	0.500	
Flow Rate, Q_{LC}	1	MGD
Column Diameter, CD_{LC}	12	ft
Water Specific Weight, γ_W @ 20° C	62.3	lb/ft^3

$$Cross\ Sectional\ Area, A_{LC} = \frac{\pi}{4}{CD_{LC}}^2 = \frac{\pi}{4} * (3.6576\ \text{m})^2 = \mathbf{10.51\ m^2}$$

$$Column\ Volume, Vol_{LC} = \frac{W_{LC}}{\gamma_W \times SG_{LC}} = \frac{30{,}000\ lb}{\left(62.3\frac{lb}{ft^3}\right)(0.5)} = \mathbf{27.25\ m^3}$$

$$Column\ Depth, L_{LC} = \frac{Vol_{LC}}{A_{LC}} = \frac{27.25\ m^3}{10.51\ m^2} = \mathbf{2.59\ m}$$

$$Velocity, V_{LC} = \frac{Q_{LC}}{A_{LC}} = \frac{\left(\frac{1*10^6 gal}{day}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1^3 m^3}{3.28^3\ ft^3}\right)\left(\frac{1\ day}{24\ hr}\right)}{10.51\ m^2} = \mathbf{15.0\frac{m}{hr}}$$

$$EBCT_{LC} = \frac{Vol_{LC}}{Q_{LC}} = \frac{27.25\ m^3}{\left(\frac{1*10^6 gal}{day}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1^3 m^3}{3.28^3\ ft^3}\right)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{10.36\ min}$$

$$Bed-Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{LC}} = \frac{1\ day}{(10.36\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{139.0\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(139.0\ \frac{BV}{day}\right)} = \mathbf{143.8\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{LC}) = (143.8\ days)\left(\frac{1 * 10^6 gal}{day}\right)\left(\frac{1\ ft^3}{7.48\ gal}\right)\left(\frac{1^3 m^3}{3.28^3\ ft^3}\right)\left(\frac{1000\ L}{1\ m^3}\right) = \mathbf{5.45 \times 10^8\ L}$$

7.1.2 Full – Scale GAC Particle Sizes

GAC ID	U.S. Mesh Size No		Corresponding Particle Size		Calculation of Average Particle Size	Average Particle Size
	Passed	Retained	Passed	Retained		
GAC A/B	12	40	1.68 mm	0.42 mm	$\frac{1.68\ mm + 0.42\ mm}{2}$	1.00 mm
GAC C	8	30	2.38 mm	0.595 mm	$\frac{2.38\ mm + 0.595\ mm}{2}$	1.49 mm
GAC D	12	30	1.68 mm	0.595 mm	$\frac{1.68\ mm + 0.595\ mm}{2}$	1.14 mm
GAC E	12	30	1.68 mm	0.595 mm	$\frac{1.68\ mm + 0.595\ mm}{2}$	1.14 mm
GAC F	12	40	1.68 mm	0.42 mm	$\frac{1.68\ mm + 0.42\ mm}{2}$	1.00 mm
GAC G	12	40	1.68 mm	0.42 mm	$\frac{1.68\ mm + 0.42\ mm}{2}$	1.00 mm

Note: The average particle sizes of 1.00 mm should be 1.05 mm, but there was a calculation error. 1.00 mm was used in the calculations for runs #2 – 10 since the error was only caught after the test was completed.

7.1.3 Full – Scale Reynold's Number Parameters

Velocity, V_{LC}	15.0	m/hr
Avg. Diameter, D_{LC} (GAC A/B, F, and G)	1.00	mm
Avg. Diameter, D_{LC} (GAC D, and E)	1.14	mm
Avg. Diameter, D_{LC} (GAC C)	1.49	mm
Kinematic Viscosity, v_w @ 20° C	1.004 X 10^{-6}	m^2/s
$Re_{LC,min}$ (Sieve No. 170 x 200)	0.39	

7.1.4 Given Small-Scale (RSSCT) Column Parameters

Column Diameter, CD_{SC}	4.76	mm
GAC Specific Gravity, SG_{SC}	0.500	
Water Density, ρ_W	0.998	g/mL
Column Depth, L_{SC} (run #2 – 10)	2.00	cm

$$Cross\ Sectional\ Area, A_{SC} = \frac{\pi}{4} {CD_{SC}}^2 = \frac{\pi}{4} * (4.76\ mm)^2 \left(\frac{1^2\ cm^2}{10^2\ mm^2}\right) = \mathbf{0.178\ cm^2}$$

$$Column\ Volume, Vol_{SC} = A_{SC} * L_{SC} = (0.178\ cm^2)(2.00\ cm)\left(\frac{1\ mL}{1\ cm^3}\right) = \mathbf{0.355\ mL} \leftarrow (\textbf{run \#2 – 10})$$

$$GAC\ Mass = m_{SC} = \rho_{SC} * Vol_S = SG_{SC} * \rho_W * Vol_S = (0.5) * \left(0.998 \frac{g}{mL}\right) * 0.355\ mL = \mathbf{0.178\ g}$$

7.1.5 Small-Scale (RSSCT) GAC Particle Sizes

Run #	U.S. Mesh Size No		Corresponding Particle Size		Calculation of Average Particle Size	Average Particle Size
	Passed	Retained	Passed	Retained		
2 – 10	170	200	0.088 mm	0.075 mm	$\frac{0.088\ mm + 0.075\ mm}{2}$	0.082 mm
11	170	200	0.088 mm	0.075 mm	$\frac{0.088\ mm + 0.075\ mm}{2}$	0.082 mm
11	140	170	0.106 mm	0.088 mm	$\frac{0.106\ mm + 0.088\ mm}{2}$	0.097 mm
11	120	140	0.124 mm	0.106 mm	$\frac{0.124\ mm + 0.106\ mm}{2}$	0.115 mm
11	100	120	0.149 mm	0.124 mm	$\frac{0.149\ mm + 0.124\ mm}{2}$	0.137 mm

7.1.6 Calculation for Small – Scale Parameters

Runs #2 – 10: Comparative Evaluation of Different GACs

GAC A/B, GAC F, and GAC G

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.00 mm	0.082 mm

$$\frac{EBCT_{SC}}{EBCT_{LC}} = \left(\frac{R_{SC}}{R_{LC}}\right)^2 = \left(\frac{\left(\frac{D_{SC}}{2}\right)}{\left(\frac{D_{LC}}{2}\right)}\right)^2 = \left(\frac{D_{SC}}{D_{LC}}\right)^2$$

$$EBCT_{SC} = EBCT_L * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\ \text{min}) * \left(\frac{0.082\ mm}{1.00\ mm}\right)^2 = 0.070\ min$$

$$Velocity,\ V_{SC} = \frac{L_{SC}}{EBCT_{SC}} = \frac{(2.00\ cm)\left(\frac{1\ m}{100\ cm}\right)}{(0.070\ \text{min})\left(\frac{60\ s}{1\ min}\right)} = 4.76 * 10^{-3}\,\frac{m}{s}$$

$$Reynold's\ Number, Re_{min} = \frac{V_{SC} * D_{SC}}{\nu_W} = \frac{\left(4.76 * 10^{-3}\,\frac{m}{s}\right)(0.082\ mm)\left(\frac{1\ m}{1000\ mm}\right)}{\left(1.004 * 10^{-6}\,\frac{m^2}{s}\right)} = 0.39$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.355\ mL}{0.070\ min} = 5.10\ \frac{mL}{min}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.070\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{20,678}\ \frac{\mathbf{BV}}{\mathbf{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(20{,}678\ \frac{BV}{day}\right)} = \mathbf{4.84\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (4.84\ days)\left(\frac{5.10\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{35.5\ L}$$

GAC D and GAC E

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.14 mm	0.082 mm

$$EBCT_{SC} = EBCT_L * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\text{ min}) * \left(\frac{0.082\ mm}{1.14\ mm}\right)^2 = 0.054\ min$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.355\ mL}{0.054\ min} = 6.63\ \frac{mL}{min}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.054\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{26,873\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(26{,}873\ \frac{BV}{day}\right)} = \mathbf{3.72\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (3.72\ days)\left(\frac{6.63\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{35.5\ L}$$

GAC C

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.49 mm	0.082 mm

$$EBCT_{SC} = EBCT_L * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\ \text{min}) * \left(\frac{0.082\ mm}{1.49\ mm}\right)^2 = 0.031\ min$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.355\ mL}{0.031\ min} = 11.32\ \frac{mL}{min}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.031\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{45,907}\ \frac{\boldsymbol{BV}}{\boldsymbol{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(45{,}907\ \frac{BV}{day}\right)} = \mathbf{2.18}\ \boldsymbol{days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (2.18\ days)\left(\frac{11.32\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{35.5}\ \boldsymbol{L}$$

Run #11 Calculations: Comparative Evaluation of Carbon A/B for Different Small – Scale GAC Particle Sizes

GAC A/B – Small – Scale 100 x 120 Mesh

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.05 mm	0.137 mm

$$EBCT_{SC} = EBCT_{LC} * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355 \text{ min}) * \left(\frac{0.137\ mm}{1.05\ mm}\right)^2 = 0.176\ min$$

$$Velocity, V_{SC} = \frac{Re_{min} * \nu_W}{D_{SC}} = \frac{(0.436)\left(1.004 * 10^{-6} \frac{m^2}{s}\right)\left(\frac{3600\ s}{1\ hr}\right)}{(0.137\ mm)\left(\frac{1\ m}{1000\ mm}\right)} = 11.47 \frac{m}{hr}$$

$$Column\ Depth, L_{SC} = V_{SC} * EBCT_{SC} = \left(11.47 \frac{m}{hr}\right)(0.176 \text{ min})\left(\frac{1\ hr}{60\ min}\right)\left(\frac{100\ cm}{1\ m}\right) = 3.37\ cm$$

$$Column\ Volume, Vol_{SC} = A_{SC} * L_{SC} = (0.178\ cm^2)(3.37\ cm)\left(\frac{1\ mL}{1\ cm^3}\right) = 0.599\ mL$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.599\ mL}{0.176\ min} = 3.42 \frac{mL}{min}$$

$$GAC\ Mass = m_{SC} = \rho_{SC} * Vol_S = SG_{SC} * \rho_W * Vol_S = (0.5) * \left(0.998 \frac{g}{mL}\right) * 0.599\ mL = \mathbf{0.299\ g}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.176\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{8,167\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(8{,}167 \frac{BV}{day}\right)} = \mathbf{12.24\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (12.24\ days)\left(\frac{3.42\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{60.3\ L}$$

GAC A/B – Small – Scale 120 x 140 Mesh

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.05 mm	0.115 mm

$$EBCT_{SC} = EBCT_{LC} * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\text{ min}) * \left(\frac{0.115\ mm}{1.05\ mm}\right)^2 = 0.124\ min$$

$$Velocity, V_{SC} = \frac{Re_{min} * \nu_W}{D_{SC}} = \frac{(0.436)\left(1.004 * 10^{-6}\frac{m^2}{s}\right)\left(\frac{3600\ s}{1\ hr}\right)}{(0.115\ mm)\left(\frac{1\ m}{1000\ mm}\right)} = 13.74\ \frac{m}{hr}$$

$$Column\ Depth, L_{SC} = V_{SC} * EBCT_{SC} = \left(13.74\frac{m}{hr}\right)(0.124\text{ min})\left(\frac{1\ hr}{60\ min}\right)\left(\frac{100\ cm}{1\ m}\right) = 2.84\ cm$$

$$Column\ Volume, Vol_{SC} = A_{SC} * L_{SC} = (0.178\ cm^2)(2.84\ cm)\left(\frac{1\ mL}{1\ cm^3}\right) = 0.505\ mL$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.505\ mL}{0.124\ min} = 4.07\ \frac{mL}{min}$$

$$GAC\ Mass = m_{SC} = \rho_{SC} * Vol_S = SG_{SC} * \rho_W * Vol_{SC} = (0.5) * \left(0.998\frac{g}{mL}\right) * 0.505\ mL = \mathbf{0.252\ g}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.124\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{11,613\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(11{,}613\frac{BV}{day}\right)} = \mathbf{8.61\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (8.61\ days)\left(\frac{4.07\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{50.5\ L}$$

GAC A/B – Small – Scale 140 x 170 Mesh

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.05 mm	0.097 mm

$$EBCT_{SC} = EBCT_{LC} * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\ \text{min}) * \left(\frac{0.097\ mm}{1.05\ mm}\right)^2 = 0.088\ min$$

$$Velocity, V_{SC} = \frac{Re_{min} * \nu_W}{D_{SC}} = \frac{(0.436)\left(1.004 * 10^{-6}\frac{m^2}{s}\right)\left(\frac{3600\ s}{1\ hr}\right)}{(0.097\ mm)\left(\frac{1\ m}{1000\ mm}\right)} = 16.25\ \frac{m}{hr}$$

$$Column\ Depth, L_{SC} = V_{SC} * EBCT_{SC} = \left(16.25\frac{m}{hr}\right)(0.088\ \text{min})\left(\frac{1\ hr}{60\ min}\right)\left(\frac{100\ cm}{1\ m}\right) = 2.38\ cm$$

$$Column\ Volume, Vol_{SC} = A_{SC} * L_{SC} = (0.178\ cm^2)(2.38\ cm)\left(\frac{1\ mL}{1\ cm^3}\right) = 0.424\ mL$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.424\ mL}{0.088\ min} = 4.82\ \frac{mL}{min}$$

$$GAC\ Mass = m_{SC} = \rho_{SC} * Vol_S = SG_{SC} * \rho_W * Vol_{SC} = (0.5) * \left(0.998\frac{g}{mL}\right) * 0.424\ mL = \mathbf{0.212\ g}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.088\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{16,364\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(16{,}364\ \frac{BV}{day}\right)} = \mathbf{6.11\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (6.11\ days)\left(\frac{4.82\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{42.4\ L}$$

GAC A/B – Small – Scale 170 x 200 Mesh

Full – Scale, D_{LC}	Small – Scale, D_{SC}
1.05 mm	0.082 mm

$$EBCT_{SC} = EBCT_L * \left(\frac{D_{SC}}{D_{LC}}\right)^2 = (10.355\text{ min}) * \left(\frac{0.082\ mm}{1.05\ mm}\right)^2 = 0.062\ min$$

$$Column\ Depth, L_{SC} = 2.00\ cm \leftarrow Manufactured\ to\ 2.00\ cm$$

$$Column\ Volume, Vol_{SC} = 0.355\ mL \leftarrow Manufactured\ to\ 0.355\ mL$$

$$Flow\ Rate, Q_{SC} = \frac{Vol_{SC}}{EBCT_{SC}} = \frac{0.355\ mL}{0.062\ min} = 5.74\ \frac{mL}{min}$$

$$GAC\ Mass = m_{SC} = \rho_{SC} * Vol_S = SG_{SC} * \rho_W * Vol_{SC} = (0.5) * \left(0.998\frac{g}{mL}\right) * 0.355\ mL = \mathbf{0.178\ g}$$

$$Bed - Volumes\ Treated\ per\ Day = \frac{1\ day}{EBCT_{SC}} = \frac{1\ day}{(0.062\ min)\left(\frac{1\ day}{1440\ min}\right)} = \mathbf{23,226\ \frac{BV}{day}}$$

$$Time\ to\ Reach\ 100{,}000\ BV = \frac{100{,}000\ BV}{\left(23{,}226\frac{BV}{day}\right)} = \mathbf{4.31\ days}$$

$$Volume\ to\ Treat\ 100{,}000\ BV = (Time\ to\ Reach\ 100{,}000\ BV)(Q_{SC}) = (4.31\ days)\left(\frac{5.74\ mL}{min}\right)\left(\frac{1440\ min}{1\ day}\right)\left(\frac{1\ L}{1000\ mL}\right) = \mathbf{35.6\ L}$$

7.2 **Raw Data**

7.2.1 GAC Run #2

Run #2		
Kunia I		
Carbon C		
Carbon C	11.32	mL/min
Bed Volume	0.355	mL
TCP Influent	0.818	ppb

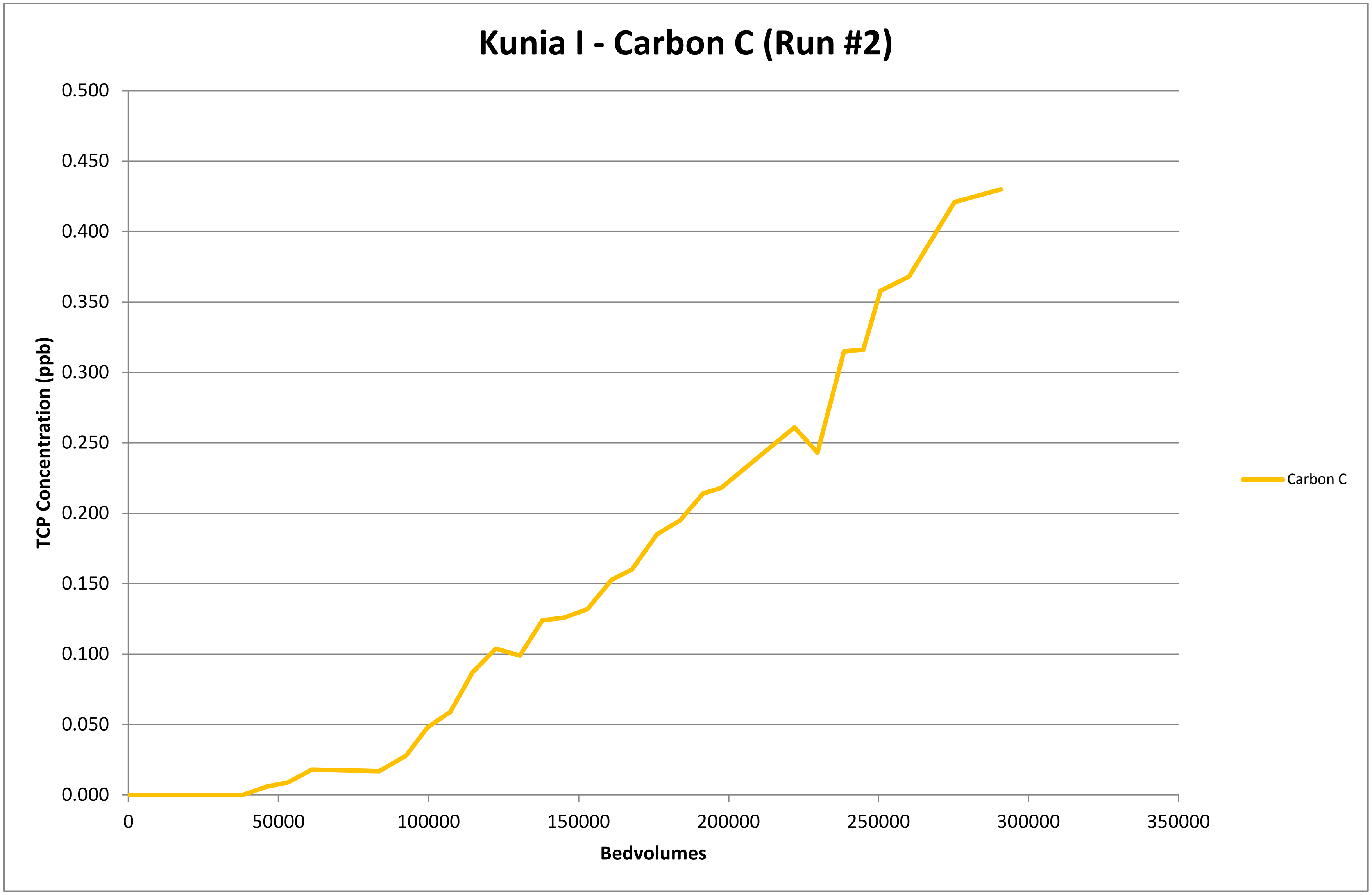
Sample ID	TCP Conc. (ppb)
K-Inf1	
K-Inf2	
K-Inf3	
Infl. Avg	0.818

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthrough (ppb)	5% Breakthrough (ppb)	10% Breakthrough (ppb)
Limit Conc. (ppb)	0.0082	0.0409	0.0818
C	3.63E-05	6.80E-05	7.85E-05

	Bed - Volumes		
	1% Breakthroug h (ppb)	5% Breakthroug h (ppb)	10% Breakthroug h (ppb)
Limit Conc. (ppb)	0.0082	0.0409	0.0818
C	51230	97142	113325

Carbon	C										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
K-C1	2/26/14 16:08	0	0	0.0	0.00	11.32	0	0	0.000	0.000	0
K-C2	2/26/14 20:05	237	237	3.9	0.16	11.32	2683	7557	0.000	0.000	5.37E-06
K-C3	2/27/14 0:03	238	475	7.9	0.33	11.32	5377	15146	0.000	0.000	1.08E-05
K-C4	2/27/14 4:12	249	724	12.1	0.50	11.32	8196	23086	0.000	0.000	1.64E-05
K-C5	2/27/14 8:04	232	956	15.9	0.66	11.32	10822	30484	0.000	0.000	2.16E-05
K-C6	2/27/14 12:04	240	1196	19.9	0.83	11.32	13539	38137	0.000	0.000	2.71E-05
K-C7	2/27/14 16:14	250	1446	24.1	1.00	11.32	16369	46109	0.006	0.007	3.27E-05
K-C8	2/27/14 19:55	221	1667	27.8	1.16	11.32	18870	53156	0.009	0.011	3.76E-05
K-C9	2/28/14 0:03	248	1915	31.9	1.33	11.32	21678	61064	0.018	0.022	4.31E-05
K-C12	2/28/14 11:49	706	2621	43.7	1.82	11.32	29670	83577	0.017	0.021	5.88E-05
K-C13	2/28/14 16:28	279	2900	48.3	2.01	11.32	32828	92473	0.028	0.034	6.49E-05
K-C14	2/28/14 20:15	227	3127	52.1	2.17	11.32	35398	99712	0.048	0.059	6.97E-05
K-C15	3/1/14 0:13	238	3365	56.1	2.34	11.32	38092	107301	0.059	0.072	7.47E-05
K-C16	3/1/14 4:05	232	3597	60.0	2.50	11.32	40718	114699	0.087	0.106	7.94E-05
K-C17	3/1/14 8:07	242	3839	64.0	2.67	11.32	43457	122415	0.104	0.127	8.42E-05
K-C18	3/1/14 12:18	251	4090	68.2	2.84	11.32	46299	130419	0.099	0.121	8.92E-05
K-C19	3/1/14 16:13	235	4325	72.1	3.00	11.32	48959	137913	0.124	0.152	9.37E-05
K-C20	3/1/14 20:01	228	4553	75.9	3.16	11.32	51540	145183	0.126	0.154	9.81E-05
K-C21	3/2/14 0:04	243	4796	79.9	3.33	11.32	54291	152932	0.132	0.161	1.03E-04
K-C22	3/2/14 4:21	257	5053	84.2	3.51	11.32	57200	161127	0.153	0.187	1.07E-04
K-C23	3/2/14 7:49	208	5261	87.7	3.65	11.32	59555	167759	0.160	0.196	1.11E-04
K-C24	3/2/14 12:10	261	5522	92.0	3.83	11.32	62509	176082	0.185	0.226	1.16E-04
K-C25	3/2/14 16:15	245	5767	96.1	4.00	11.32	65282	183894	0.195	0.238	1.20E-04
K-C26	3/2/14 20:11	236	6003	100.0	4.17	11.32	67954	191420	0.214	0.262	1.24E-04
K-C27	3/2/14 23:24	193	6196	103.3	4.30	11.32	70139	197574	0.218	0.267	1.27E-04
K-C30	3/3/14 12:09	765	6961	116.0	4.83	11.32	78799	221968	0.261	0.319	1.39E-04
K-C31	3/3/14 16:09	240	7201	120.0	5.00	11.32	81515	229621	0.243	0.297	1.43E-04
K-C32	3/3/14 20:47	278	7479	124.6	5.19	11.32	84662	238485	0.315	0.385	1.47E-04

K-C33	3/4/14 0:07	200	7679	128.0	5.33	11.32	86926	244863	0.316	0.386	1.49E-04
K-C34	3/4/14 3:07	180	7859	131.0	5.46	11.32	88964	250602	0.358	0.438	1.52E-04
K-C35	3/4/14 8:05	298	8157	135.9	5.66	11.32	92337	260105	0.368	0.450	1.55E-04
K-C36	3/4/14 16:03	478	8635	143.9	6.00	11.32	97748	275347	0.421	0.515	1.61E-04
K-C37	3/5/14 0:05	482	9117	151.9	6.33	11.32	103204	290717	0.430	0.526	1.66E-04


Kunia I - Carbon C (Run #2)
TCP Concentration (ppb)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
50000
100000
150000
200000
250000
300000
350000
Bedvolumes
Carbon C

7.2.2 GAC Run #3

Run #3		
Kunia I		
Carbon A/B, D, E, F		
A/B	5.1	mL/min
D	6.63	mL/min
E	6.63	mL/min
F	6.63	mL/min
Bed Volume	0.355	mL
TCP Influent	0.794	ppb

Sample ID	TCP Conc. (ppb)
K-Infl1	0.799
K-Infl2	0.792
K-Infl3	0.790
Influent Avg.	0.794

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthrough (ppb)	5% Breakthrough (ppb)	10% Breakthrough (ppb)
Limit Conc. (ppb)	0.0079	0.0397	0.0794
A/B	2.554E-04	3.090E-04	3.433E-04
D	2.040E-04	2.843E-04	3.037E-04
E	1.029E-04	1.705E-04	2.084E-04
F	8.999E-05	1.656E-04	2.114E-04

	Bed - Volumes		
	1% Breakthrough (ppb)	5% Breakthrough (ppb)	10% Breakthrough (ppb)
Limit Conc. (ppb)	0.0079	0.0397	0.0794
A/B	161229	196004	219659
D	128820	181160	194532
E	64960	108739	134780
F	56787	106151	137539

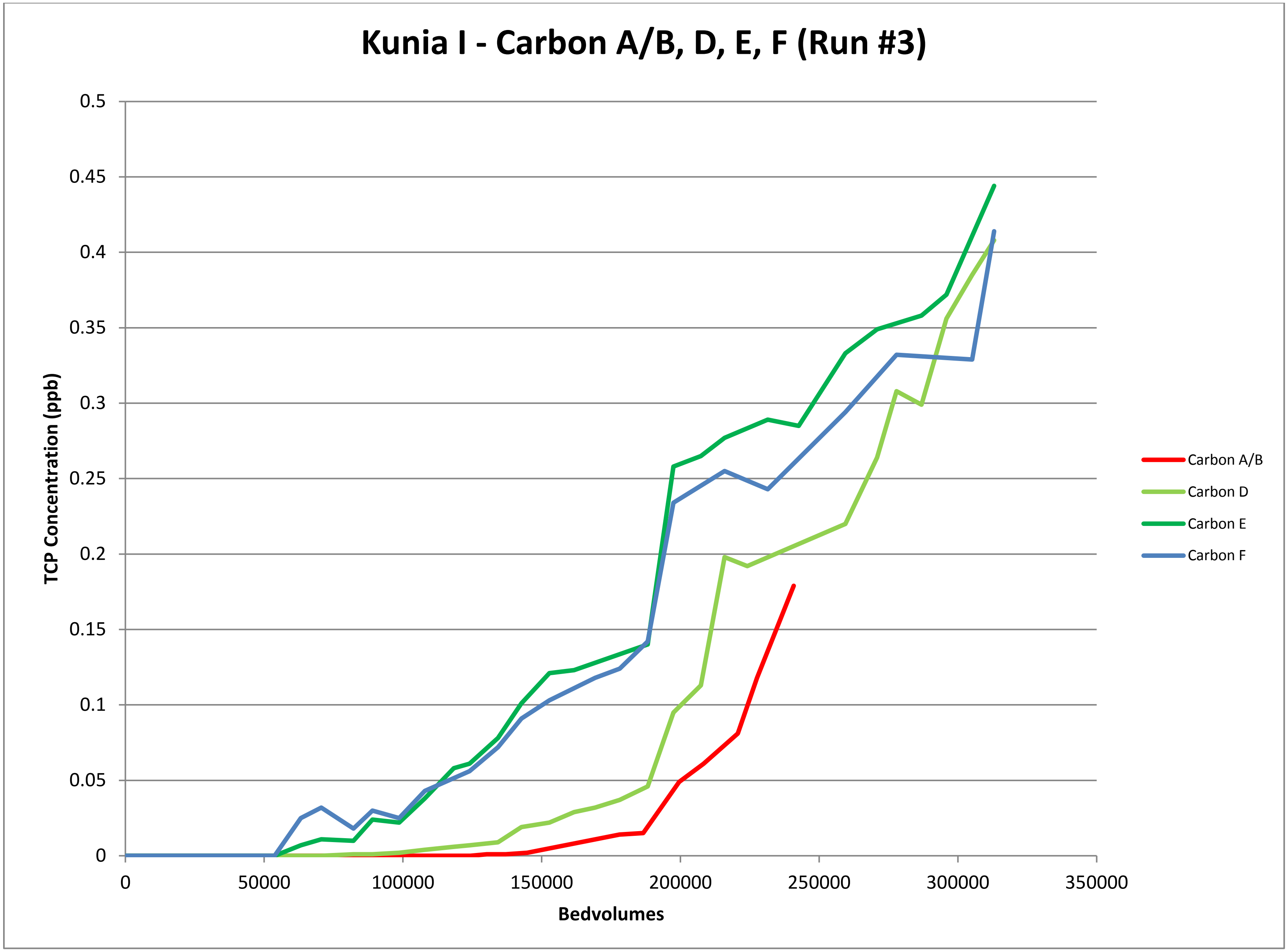
Carbon	A/B										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
K-A/B1	3/13/14 8:17	17	17	0.3	0.01	5.1	87	244	0	0.000	3.88E-07
K-A/B2	3/13/14 16:00	463	480	8.0	0.33	5.1	2448	6896	0	0.000	1.09E-05
K-A/B3	3/14/14 0:09	489	969	16.2	0.67	5.1	4942	13921	0	0.000	2.21E-05
K-A/B4	3/14/14 8:22	493	1462	24.4	1.02	5.1	7456	21003	0	0.000	3.33E-05
K-A/B5	3/14/14 16:15	473	1935	32.3	1.34	5.1	9869	27799	0	0.000	4.41E-05
K-A/B7	3/15/14 8:00	945	2880	48.0	2.00	5.1	14688	41375	0	0.000	6.57E-05
K-A/B8	3/15/14 16:26	506	3386	56.4	2.35	5.1	17269	48644	0	0.000	7.72E-05
K-A/B9	3/15/14 23:00	394	3780	63.0	2.63	5.1	19278	54304	0	0.000	8.62E-05
K-A/B10	3/16/14 9:18	618	4398	73.3	3.05	5.1	22430	63183	0	0.000	1.00E-04
K-A/B11	3/16/14 15:25	367	4765	79.4	3.31	5.1	24302	68455	0	0.000	1.09E-04
K-A/B12	3/17/14 0:00	515	5280	88.0	3.67	5.1	26928	75854	0	0.000	1.20E-04
K-A/B13	3/17/14 8:15	495	5775	96.3	4.01	5.1	29453	82965	0	0.000	1.32E-04
K-A/B14	3/17/14 17:38	563	6338	105.6	4.40	5.1	32324	91053	0	0.000	1.45E-04
K-A/B15	3/17/14 22:40	302	6640	110.7	4.61	5.1	33864	95392	0	0.000	1.51E-04
K-A/B16	3/18/14 7:50	550	7190	119.8	4.99	5.1	36669	103293	0	0.000	1.64E-04
K-A/B17	3/18/14 15:20	450	7640	127.3	5.31	5.1	38964	109758	0	0.000	1.74E-04
K-A/B18	3/19/14 0:20	540	8180	136.3	5.68	5.1	41718	117515	0	0.000	1.87E-04
K-A/B19	3/19/14 8:15	475	8655	144.3	6.01	5.1	44141	124339	0	0.000	1.97E-04
K-AB20	3/19/14 15:00	405	9060	151.0	6.29	5.1	46206	130158	0.001	0.001	2.07E-04
K-AB21	3/19/14 23:00	480	9540	159.0	6.63	5.1	48654	137054	0.001	0.001	2.18E-04
K-AB22	3/20/14 7:57	537	10077	168.0	7.00	5.1	51393	144768	0.002	0.003	2.30E-04
K-AB27	3/21/14 22:33	2316	12393	206.6	8.61	5.1	63204	178040	0.014	0.018	2.82E-04
K-AB28	3/22/14 8:30	597	12990	216.5	9.02	5.1	66249	186617	0.015	0.019	2.95E-04
K-AB30	3/22/14 23:30	900	13890	231.5	9.65	5.1	70839	199546	0.049	0.062	3.14E-04
K-AB31	3/23/14 9:43	613	14503	241.7	10.07	5.1	73965	208353	0.061	0.077	3.27E-04
K-AB33	3/24/14 0:00	857	15360	256.0	10.67	5.1	78336	220665	0.081	0.102	3.45E-04
K-AB34	3/24/14 8:00	480	15840	264.0	11.00	5.1	80784	227561	0.118	0.149	3.54E-04
K-AB36	3/24/14 23:24	924	16764	279.4	11.64	5.1	85496	240835	0.179	0.226	3.70E-04

Carbon	D										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
K-D1	3/13/14 8:09	9	9	0.2	0.01	6.63	60	168	0	0.000	2.66806E-07
K-D2	3/13/14 16:00	471	480	8.0	0.33	6.63	3182	8965	0	0.000	1.42E-05
K-D3	3/14/14 0:09	489	969	16.1	0.67	6.63	6424	18097	0	0.000	2.87E-05
K-D4	3/14/14 8:22	493	1462	24.4	1.02	6.63	9693	27304	0	0.000	4.33E-05
K-D5	3/14/14 16:15	473	1935	32.3	1.34	6.63	12829	36138	0	0.000	5.74E-05
K-D6	3/15/14 0:00	465	2400	40.0	1.67	6.63	15912	44823	0	0.000	7.11E-05
K-D7	3/15/14 8:00	480	2880	48.0	2.00	6.63	19094	53787	0	0.000	8.54E-05
K-D8	3/15/14 16:26	506	3386	56.4	2.35	6.63	22449	63237	0	0.000	1.00E-04
K-D9	3/15/14 23:00	394	3780	63.0	2.63	6.63	25061	70595	0	0.000	1.12E-04
K-D10	3/16/14 9:18	618	4398	73.3	3.05	6.63	29159	82137	0.001	0.001	1.30E-04
K-D11	3/16/14 15:25	367	4765	79.4	3.31	6.63	31592	88991	0.001	0.001	1.41E-04
K-D12	3/17/14 0:00	515	5280	88.0	3.67	6.63	35006	98610	0.002	0.003	1.56E-04
K-D13	3/17/14 8:15	495	5775	96.2	4.01	6.63	38288	107854	0.004	0.005	1.71E-04
K-D14	3/17/14 17:38	563	6338	105.6	4.40	6.63	42021	118369	0.006	0.008	1.88E-04
K-D15	3/17/14 22:40	302	6640	110.7	4.61	6.63	44023	124009	0.007	0.009	1.96E-04
K-D16	3/18/14 7:50	550	7190	119.8	4.99	6.63	47670	134281	0.009	0.011	2.13E-04
K-D17	3/18/14 15:20	450	7640	127.3	5.31	6.63	50653	142685	0.019	0.024	2.26E-04
K-D18	3/19/14 0:20	540	8180	136.3	5.68	6.63	54233	152770	0.022	0.028	2.41E-04
K-D19	3/19/14 8:15	475	8655	144.2	6.01	6.63	57383	161641	0.029	0.037	2.55E-04
K-D20	3/19/14 15:00	405	9060	151.0	6.29	6.63	60068	169205	0.032	0.040	2.66E-04
K-D21	3/19/14 23:00	480	9540	159.0	6.63	6.63	63250	178170	0.037	0.047	2.80E-04
K-D22	3/20/14 7:57	537	10077	168.0	7.00	6.63	66811	188199	0.046	0.058	2.95E-04
K-D23	3/20/14 16:15	498	10575	176.3	7.34	6.63	70112	197499	0.095	0.120	3.08E-04
K-D24	3/21/14 1:04	529	11104	185.1	7.71	6.63	73620	207379	0.113	0.142	3.21E-04
K-D25	3/21/14 8:43	459	11563	192.7	8.03	6.63	76663	215951	0.198	0.249	3.32E-04
K-D26	3/21/14 16:00	437	12000	200.0	8.33	6.63	79560	224113	0.192	0.242	3.41E-04
K-D30	3/22/14 23:30	1890	13890	231.5	9.65	6.63	92091	259410	0.220	0.277	3.82E-04
K-D31	3/23/14 9:43	613	14503	241.7	10.07	6.63	96155	270859	0.264	0.333	3.94E-04
K-D32	3/23/14 16:00	377	14880	248.0	10.33	6.63	98654	277900	0.308	0.388	4.01E-04

K-D33	3/24/14 0:00	480	15360	256.0	10.67	6.63	101837	286864	0.299	0.377	4.10E-04
K-D34	3/24/14 8:00	480	15840	264.0	11.00	6.63	105019	295829	0.356	0.449	4.18E-04
K-D35	3/24/14 16:20	500	16340	272.3	11.35	6.63	108334	305167	0.385	0.485	4.25E-04
K-D36	3/24/14 23:24	424	16764	279.4	11.64	6.63	111145	313085	0.408	0.514	4.31E-04

Carbon	E										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
K-E1	3/13/14 8:09	9	9	0.2	0.01	6.63	60	168	0	0.000	2.66806E-07
K-E2	3/13/14 16:00	471	480	8.0	0.33	6.63	3182	8965	0	0.000	1.42E-05
K-E3	3/14/14 0:09	489	969	16.1	0.67	6.63	6424	18097	0	0.000	2.87E-05
K-E4	3/14/14 8:22	493	1462	24.4	1.02	6.63	9693	27304	0	0.000	4.33E-05
K-E5	3/14/14 16:15	473	1935	32.3	1.34	6.63	12829	36138	0	0.000	5.74E-05
K-E6	3/15/14 0:00	465	2400	40.0	1.67	6.63	15912	44823	0	0.000	7.11E-05
K-E7	3/15/14 8:00	480	2880	48.0	2.00	6.63	19094	53787	0	0.000	8.54E-05
K-E8	3/15/14 16:26	506	3386	56.4	2.35	6.63	22449	63237	0.007	0.009	1.00E-04
K-E9	3/15/14 23:00	394	3780	63.0	2.63	6.63	25061	70595	0.011	0.014	1.12E-04
K-E10	3/16/14 9:18	618	4398	73.3	3.05	6.63	29159	82137	0.010	0.013	1.30E-04
K-E11	3/16/14 15:25	367	4765	79.4	3.31	6.63	31592	88991	0.024	0.030	1.40E-04
K-E12	3/17/14 0:00	515	5280	88.0	3.67	6.63	35006	98610	0.022	0.028	1.55E-04
K-E13	3/17/14 8:15	495	5775	96.2	4.01	6.63	38288	107854	0.038	0.048	1.69E-04
K-E14	3/17/14 17:38	563	6338	105.6	4.40	6.63	42021	118369	0.058	0.073	1.85E-04
K-E15	3/17/14 22:40	302	6640	110.7	4.61	6.63	44023	124009	0.061	0.077	1.93E-04
K-E16	3/18/14 7:50	550	7190	119.8	4.99	6.63	47670	134281	0.078	0.098	2.08E-04
K-E17	3/18/14 15:20	450	7640	127.3	5.31	6.63	50653	142685	0.101	0.127	2.19E-04
K-E18	3/19/14 0:20	540	8180	136.3	5.68	6.63	54233	152770	0.121	0.152	2.33E-04
K-E19	3/19/14 8:15	475	8655	144.2	6.01	6.63	57383	161641	0.123	0.155	2.45E-04
K-E22	3/20/14 7:57	1422	10077	168.0	7.00	6.63	66811	188199	0.140	0.176	2.79E-04
K-E23	3/20/14 16:15	498	10575	176.3	7.34	6.63	70112	197499	0.258	0.325	2.89E-04
K-E24	3/21/14 1:04	529	11104	185.1	7.71	6.63	73620	207379	0.265	0.334	3.00E-04
K-E25	3/21/14 8:43	459	11563	192.7	8.03	6.63	76663	215951	0.277	0.349	3.09E-04
K-E27	3/21/14 22:33	830	12393	206.5	8.61	6.63	82166	231452	0.289	0.364	3.24E-04
K-E28	3/22/14 8:30	597	12990	216.5	9.02	6.63	86124	242602	0.285	0.359	3.36E-04
K-E30	3/22/14 23:30	900	13890	231.5	9.65	6.63	92091	259410	0.333	0.420	3.51E-04
K-E31	3/23/14 9:43	613	14503	241.7	10.07	6.63	96155	270859	0.349	0.440	3.61E-04
K-E33	3/24/14 0:00	857	15360	256.0	10.67	6.63	101837	286864	0.358	0.451	3.75E-04
K-E34	3/24/14 8:00	480	15840	264.0	11.00	6.63	105019	295829	0.372	0.469	3.83E-04
K-E36	3/24/14 23:24	924	16764	279.4	11.64	6.63	111145	313085	0.444	0.559	3.95E-04

Carbon	F										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
K-F1	3/13/14 8:09	9	9	0.2	0.01	6.63	60	168	0	0.000	2.66806E-07
K-F2	3/13/14 16:00	471	480	8.0	0.33	6.63	3182	8965	0	0.000	1.42E-05
K-F3	3/14/14 0:09	489	969	16.1	0.67	6.63	6424	18097	0	0.000	2.87E-05
K-F4	3/14/14 8:22	493	1462	24.4	1.02	6.63	9693	27304	0	0.000	4.33E-05
K-F5	3/14/14 16:15	473	1935	32.3	1.34	6.63	12829	36138	0	0.000	5.74E-05
K-F6	3/15/14 0:00	465	2400	40.0	1.67	6.63	15912	44823	0	0.000	7.11E-05
K-F7	3/15/14 8:00	480	2880	48.0	2.00	6.63	19094	53787	0	0.000	8.54E-05
K-F8	3/15/14 16:26	506	3386	56.4	2.35	6.63	22449	63237	0.025	0.031	9.99E-05
K-F9	3/15/14 23:00	394	3780	63.0	2.63	6.63	25061	70595	0.032	0.040	1.11E-04
K-F10	3/16/14 9:18	618	4398	73.3	3.05	6.63	29159	82137	0.018	0.023	1.29E-04
K-F11	3/16/14 15:25	367	4765	79.4	3.31	6.63	31592	88991	0.030	0.038	1.39E-04
K-F12	3/17/14 0:00	515	5280	88.0	3.67	6.63	35006	98610	0.025	0.031	1.54E-04
K-F13	3/17/14 8:15	495	5775	96.2	4.01	6.63	38288	107854	0.043	0.054	1.68E-04
K-F15	3/17/14 22:40	865	6640	110.7	4.61	6.63	44023	124009	0.056	0.071	1.92E-04
K-F16	3/18/14 7:50	550	7190	119.8	4.99	6.63	47670	134281	0.072	0.091	2.07E-04
K-F17	3/18/14 15:20	450	7640	127.3	5.31	6.63	50653	142685	0.091	0.115	2.19E-04
K-F18	3/19/14 0:20	540	8180	136.3	5.68	6.63	54233	152770	0.103	0.130	2.33E-04
K-F20	3/19/14 15:00	880	9060	151.0	6.29	6.63	60068	169205	0.118	0.149	2.55E-04
K-F21	3/19/14 23:00	480	9540	159.0	6.63	6.63	63250	178170	0.124	0.156	2.67E-04
K-F22	3/20/14 7:57	537	10077	168.0	7.00	6.63	66811	188199	0.142	0.179	2.80E-04
K-F23	3/20/14 16:15	498	10575	176.3	7.34	6.63	70112	197499	0.234	0.295	2.90E-04
K-F25	3/21/14 8:43	988	11563	192.7	8.03	6.63	76663	215951	0.255	0.321	3.10E-04
K-F27	3/21/14 22:33	830	12393	206.5	8.61	6.63	82166	231452	0.243	0.306	3.27E-04
K-F30	3/22/14 23:30	1497	13890	231.5	9.65	6.63	92091	259410	0.294	0.370	3.55E-04
K-F32	3/23/14 16:00	990	14880	248.0	10.33	6.63	98654	277900	0.332	0.418	3.72E-04
K-F35	3/24/14 16:20	1460	16340	272.3	11.35	6.63	108334	305167	0.329	0.415	3.98E-04
K-F36	3/24/14 23:24	424	16764	279.4	11.64	6.63	111145	313085	0.414	0.522	4.04E-04



Kunia I - Carbon A/B, D, E, F (Run #3)
TCP Concentration (ppb)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50000
100000
150000
200000
250000
300000
350000
Bedvolumes
Carbon A/B
Carbon D
Carbon E
Carbon F

7.2.3 GAC Run #4

Run #4		
Waipahu #3		
Carbon D, E, F		
D	5.66	mL/min
E	5.66	mL/min
F	4.35	mL/min
Bed Volume	0.355	mL
TCP Influent	0.641	ppb

Sample	TCP Conc. (ppb)
W_Inf1	0.517
W_Inf2	0.536
W_Inf3	0.608
Influent Avg.	0.554

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthrough (ppb)	5% Breakthough (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0064	0.0321	0.0641
D	1.764E-04	2.188E-04	2.543E-04
E	7.341E-05	1.104E-04	1.978E-04
F	1.469E-04	2.016E-04	2.359E-04

	Bed - Volumes		
	1% Breakthrough (ppb)	5% Breakthough (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0064	0.0321	0.0641
D	159467	199164	234461
E	66507	101033	186156
F	132957	183896	218547

Carbon	D										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-D1	4/7/14 15:45	0	0	0.0	0.0	6.54	0	0	0.000	0.000	0
W-D2	4/7/14 23:35	470	470	7.8	0.3	6.54	3074	8659	0.000	0.000	9.59E-06
W-D3	4/8/14 8:07	512	982	16.4	0.7	6.68	6494	18293	0.000	0.000	2.03E-05
W-D4	4/8/14 14:47	400	1382	23.0	1.0	6.13	8946	25200	0.000	0.000	2.79E-05
W-D5	4/8/14 23:40	533	1915	31.9	1.3	5.58	11920	33578	0.000	0.000	3.72E-05
W-D6	4/9/14 8:25	525	2440	40.7	1.7	5.62	14871	41889	0.000	0.000	4.64E-05
W-D8	4/9/14 23:20	895	3335	55.6	2.3	5.62	19900	56058	0.000	0.000	6.21E-05
W-D10	4/10/14 14:46	926	4261	71.0	3.0	5.62	25105	70717	0.001	0.002	7.83E-05
W-D11	4/10/14 22:25	459	4720	78.7	3.3	5.45	27606	77764	0.000	0.000	8.61E-05
W-D12	4/11/14 8:20	595	5315	88.6	3.7	5.45	30849	86898	0.000	0.000	9.63E-05
W-D13	4/11/14 13:45	325	5640	94.0	3.9	5.45	32620	91888	0.000	0.000	1.02E-04
W-D14	4/11/14 23:45	600	6240	104.0	4.3	5.45	35890	101099	0.000	0.000	1.12E-04
W-D15	4/12/14 9:12	567	6807	113.4	4.7	5.45	38980	109804	0.000	0.000	1.22E-04
W-D16	4/12/14 15:43	391	7198	120.0	5.0	5.20	41014	115531	0.000	0.000	1.28E-04
W-D17	4/12/14 22:43	420	7618	127.0	5.3	5.20	43198	121683	0.001	0.002	1.35E-04
W-D18	4/13/14 10:19	696	8314	138.6	5.8	5.20	46817	131878	0.001	0.002	1.46E-04
W-D19	4/13/14 15:57	338	8652	144.2	6.0	5.20	48574	136829	0.002	0.004	1.52E-04
W-D20	4/13/14 22:48	411	9063	151.0	6.3	5.20	50712	142849	0.003	0.005	1.58E-04
W-D21	4/14/14 8:33	585	9648	160.8	6.7	5.20	53754	151418	0.004	0.007	1.68E-04
W-D23	4/14/14 23:45	912	10560	176.0	7.3	5.20	58496	164777	0.008	0.014	1.82E-04
W-D24	4/15/14 8:07	502	11062	184.4	7.7	5.20	61106	172130	0.011	0.020	1.90E-04
W-D25	4/15/14 14:45	398	11460	191.0	8.0	5.20	63176	177960	0.013	0.023	1.96E-04
W-D26	4/15/14 22:49	484	11944	199.1	8.3	5.54	65857	185513	0.023	0.042	2.04E-04
W-D27	4/16/14 9:45	656	12600	210.0	8.8	5.54	69492	195751	0.028	0.051	2.15E-04
W-D28	4/16/14 15:09	324	12924	215.4	9.0	5.54	71286	200807	0.034	0.061	2.21E-04
W_D29	4/16/14 23:10	481	13405	223.4	9.3	5.54	73951	208313	0.041	0.074	2.28E-04
W_D30	4/17/14 8:28	558	13963	232.7	9.7	5.54	77043	217021	0.043	0.078	2.37E-04
W_D31	4/17/14 15:39	431	14394	239.9	10.0	5.54	79430	223747	0.053	0.096	2.44E-04
W_D32	4/17/14 23:20	461	14855	247.6	10.3	5.54	81984	230941	0.059	0.106	2.51E-04
W_D34	4/18/14 15:33	973	15828	263.8	11.0	5.54	87375	246126	0.081	0.146	2.65E-04
W_D35	4/18/14 22:07	394	16222	270.4	11.3	5.54	89557	252274	0.076	0.137	2.71E-04

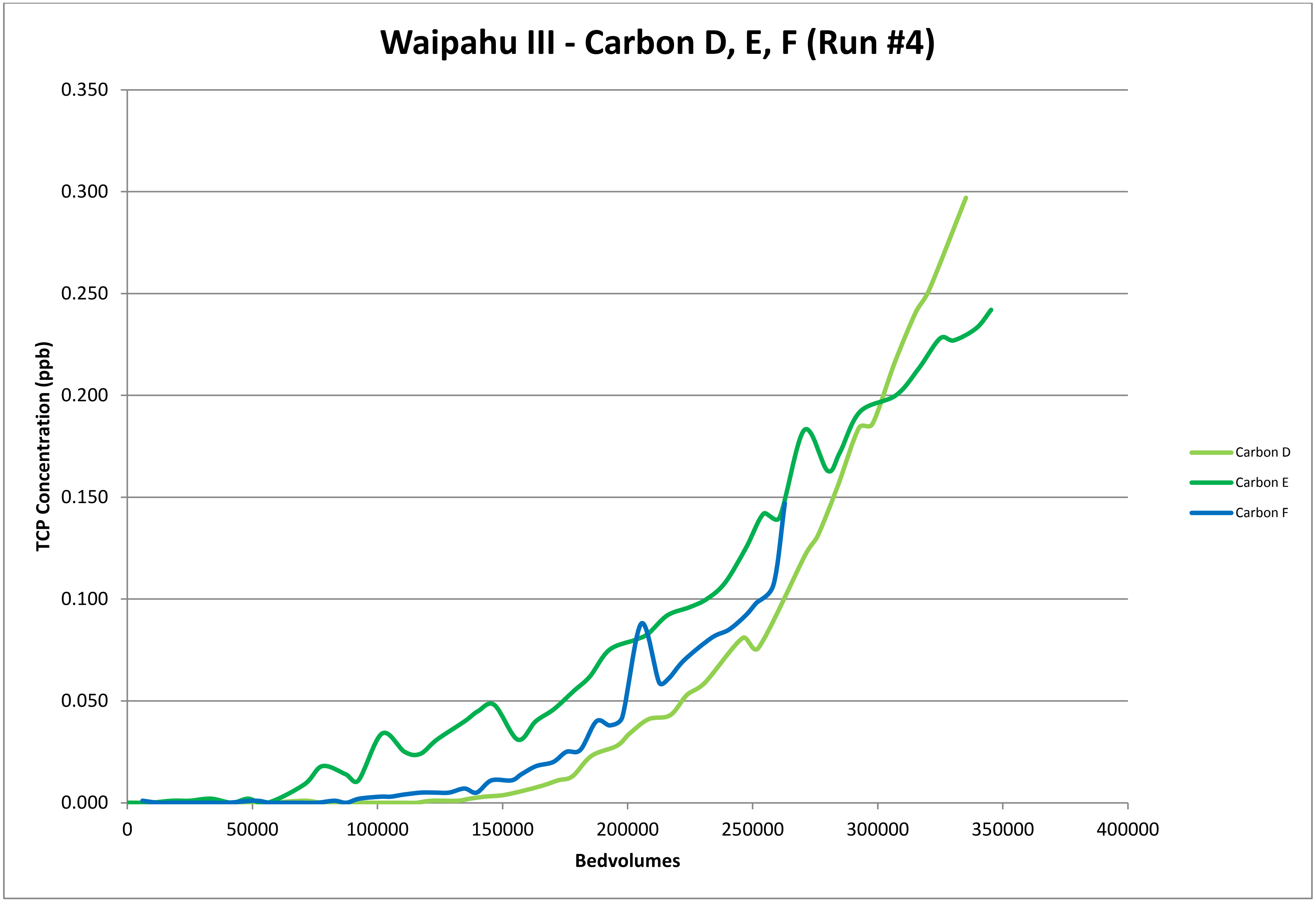
W-D37	4/19/14 18:16	1209	17431	290.5	12.1	5.54	96255	271142	0.122	0.220	2.88E-04
W-D38	4/19/14 23:26	310	17741	295.7	12.3	5.54	97973	275979	0.131	0.236	2.92E-04
W-D39	4/20/14 7:51	505	18246	304.1	12.7	5.54	100770	283860	0.155	0.280	2.98E-04
W-D40	4/20/14 17:02	551	18797	313.3	13.1	5.54	103823	292459	0.184	0.332	3.04E-04
W-D41	4/20/14 22:50	348	19145	319.1	13.3	5.54	105751	297890	0.186	0.336	3.08E-04
W-D42	4/21/14 8:18	568	19713	328.5	13.7	5.54	108898	306754	0.216	0.390	3.14E-04
W-D43	4/21/14 17:24	546	20259	337.6	14.1	5.54	111922	315274	0.241	0.435	3.20E-04
W-D44	4/21/14 23:07	343	20602	343.4	14.3	5.54	113823	320627	0.252	0.455	3.23E-04
W-D46	4/22/14 14:44	937	21539	359.0	15.0	5.54	119014	335250	0.297	0.536	3.30E-04

Carbon	E										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-E1	4/7/14 15:45	0	0	0.0	0.0	6.54	0	0	0.000	0.000	0
W-E2	4/7/14 23:35	470	470	7.8	0.3	6.54	3074	8659	0.000	0.000	9.59E-06
W-E3	4/8/14 8:07	512	982	16.4	0.7	6.46	6381	17976	0.001	0.002	1.99E-05
W-E4	4/8/14 14:47	400	1382	23.0	1.0	6.09	8817	24838	0.001	0.002	2.75E-05
W-E5	4/8/14 23:40	533	1915	31.9	1.3	5.74	11877	33456	0.002	0.004	3.70E-05
W-E6	4/9/14 8:25	525	2440	40.7	1.7	5.67	14853	41841	0.000	0.000	4.63E-05
W-E7	4/9/14 15:09	404	2844	47.4	2.0	5.67	17144	48293	0.002	0.004	5.34E-05
W-E8	4/9/14 23:20	491	3335	55.6	2.3	5.62	19904	56066	0.000	0.000	6.20E-05
W-E10	4/10/14 14:46	926	4261	71.0	3.0	5.62	25108	70726	0.009	0.016	7.80E-05
W-E11	4/10/14 22:25	459	4720	78.7	3.3	5.58	27669	77941	0.018	0.032	8.57E-05
W-E12	4/11/14 8:20	595	5315	88.6	3.7	5.58	30989	87293	0.014	0.025	9.58E-05
W-E13	4/11/14 13:45	325	5640	94.0	3.9	5.58	32803	92401	0.011	0.020	1.01E-04
W-E14	4/11/14 23:45	600	6240	104.0	4.3	5.58	36151	101832	0.034	0.061	1.11E-04
W-E15	4/12/14 9:12	567	6807	113.4	4.7	5.65	39354	110857	0.025	0.045	1.21E-04
W-E16	4/12/14 15:43	391	7198	120.0	5.0	5.65	41563	117080	0.024	0.043	1.27E-04
W-E17	4/12/14 22:43	420	7618	127.0	5.3	5.65	43936	123764	0.031	0.056	1.34E-04
W-E18	4/13/14 10:19	696	8314	138.6	5.8	5.65	47869	134841	0.040	0.072	1.46E-04
W-E19	4/13/14 15:57	338	8652	144.2	6.0	5.65	49778	140221	0.045	0.081	1.51E-04
W-E20	4/13/14 22:48	411	9063	151.0	6.3	5.65	52100	146762	0.048	0.087	1.58E-04
W-E21	4/14/14 8:33	585	9648	160.8	6.7	5.65	55406	156072	0.031	0.056	1.68E-04
W-E22	4/14/14 16:05	452	10100	168.3	7.0	5.65	57960	163266	0.040	0.072	1.75E-04
W-E23	4/14/14 23:45	460	10560	176.0	7.3	5.65	60559	170587	0.046	0.083	1.82E-04
W-E24	4/15/14 8:07	502	11062	184.4	7.7	5.65	63395	178577	0.055	0.099	1.90E-04
W-E25	4/15/14 14:45	398	11460	191.0	8.0	5.65	65644	184911	0.062	0.112	1.97E-04
W-E26	4/15/14 22:49	484	11944	199.1	8.3	5.65	68378	192614	0.075	0.135	2.04E-04
W-E27	4/16/14 9:45	656	12600	210.0	8.8	5.65	72085	203055	0.080	0.144	2.14E-04
W-E28	4/16/14 15:09	324	12924	215.4	9.0	5.65	73915	208212	0.083	0.150	2.19E-04
W-E29	4/16/14 23:10	481	13405	223.4	9.3	5.65	76633	215867	0.092	0.166	2.26E-04
W_E30	4/17/14 8:28	558	13963	232.7	9.7	5.65	79785	224748	0.096	0.173	2.34E-04
W_E31	4/17/14 15:39	431	14394	239.9	10.0	5.65	82221	231607	0.100	0.181	2.40E-04
W_E32	4/17/14 23:20	461	14855	247.6	10.3	5.65	84825	238944	0.108	0.195	2.47E-04

W_E33	4/18/14 8:02	522	15377	256.3	10.7	5.65	87775	247252	0.125	0.226	2.54E-04
W_E34	4/18/14 15:33	451	15828	263.8	11.0	5.65	90323	254430	0.142	0.256	2.60E-04
W_E35	4/18/14 22:07	394	16222	270.4	11.3	5.65	92549	260701	0.140	0.253	2.65E-04
W-E36	4/19/14 8:31	624	16846	280.8	11.7	5.65	96074	270632	0.183	0.330	2.72E-04
W-E37	4/19/14 18:16	585	17431	290.5	12.1	5.65	99380	279943	0.163	0.294	2.80E-04
W-E38	4/19/14 23:26	310	17741	295.7	12.3	5.65	101131	284877	0.172	0.310	2.83E-04
W-E39	4/20/14 7:51	505	18246	304.1	12.7	5.65	103984	292914	0.192	0.347	2.89E-04
W-E41	4/20/14 22:50	899	19145	319.1	13.3	5.65	109064	307222	0.200	0.361	2.99E-04
W-E42	4/21/14 8:18	568	19713	328.5	13.7	5.65	112273	316262	0.213	0.384	3.05E-04
W-E43	4/21/14 17:24	546	20259	337.6	14.1	5.65	115358	324952	0.228	0.412	3.11E-04
W-E44	4/21/14 23:07	343	20602	343.4	14.3	5.65	117296	330411	0.227	0.410	3.15E-04
W-E45	4/22/14 8:32	565	21167	352.8	14.7	5.65	120488	339403	0.233	0.421	3.20E-04
W-E46	4/22/14 14:44	372	21539	359.0	15.0	5.65	122590	345324	0.242	0.437	3.24E-04

Carbon	F										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-F1	4/7/14 15:45	0	0	0.0	0.0	4.57	0	0	0.000	0.000	0
W-F2	4/7/14 23:35	470	470	7.8	0.3	4.57	2148	6050	0.001	0.002	6.69E-06
W-F3	4/8/14 8:07	512	982	16.4	0.7	4.37	4385	12353	0.000	0.000	1.37E-05
W-F4	4/8/14 14:47	400	1382	23.0	1.0	4.38	6137	17288	0.000	0.000	1.91E-05
W-F5	4/8/14 23:40	533	1915	31.9	1.3	4.40	8483	23894	0.000	0.000	2.65E-05
W-F6	4/9/14 8:25	525	2440	40.7	1.7	3.98	10572	29780	0.000	0.000	3.30E-05
W-F7	4/9/14 15:09	404	2844	47.4	2.0	4.00	12188	34333	0.000	0.000	3.80E-05
W-F8	4/9/14 23:20	491	3335	55.6	2.3	4.00	14152	39865	0.000	0.000	4.42E-05
W-F10	4/10/14 14:46	926	4261	71.0	3.0	4.37	18199	51264	0.001	0.002	5.68E-05
W-F11	4/10/14 22:25	459	4720	78.7	3.3	4.39	20214	56940	0.000	0.000	6.31E-05
W-F12	4/11/14 8:20	595	5315	88.6	3.7	4.39	22826	64298	0.000	0.000	7.12E-05
W-F13	4/11/14 13:45	325	5640	94.0	3.9	4.39	24252	68317	0.000	0.000	7.57E-05
W-F14	4/11/14 23:45	600	6240	104.0	4.3	4.39	26886	75737	0.000	0.000	8.39E-05
W-F15	4/12/14 9:12	567	6807	113.4	4.7	4.39	29376	82748	0.001	0.002	9.16E-05
W-F16	4/12/14 15:43	391	7198	120.0	5.0	4.34	31073	87528	0.000	0.000	9.69E-05
W-F17	4/12/14 22:43	420	7618	127.0	5.3	4.34	32895	92663	0.002	0.004	1.03E-04
W-F18	4/13/14 10:19	696	8314	138.6	5.8	4.34	35916	101172	0.003	0.005	1.12E-04
W-F19	4/13/14 15:57	338	8652	144.2	6.0	4.34	37383	105304	0.003	0.005	1.17E-04
W-F20	4/13/14 22:48	411	9063	151.0	6.3	4.34	39167	110329	0.004	0.007	1.22E-04
W-F21	4/14/14 8:33	585	9648	160.8	6.7	4.34	41706	117480	0.005	0.009	1.30E-04
W-F22	4/14/14 16:05	452	10100	168.3	7.0	4.34	43667	123006	0.005	0.009	1.36E-04
W-F23	4/14/14 23:45	460	10560	176.0	7.3	4.34	45664	128630	0.005	0.009	1.42E-04
W-F24	4/15/14 8:07	502	11062	184.4	7.7	4.34	47842	134767	0.007	0.013	1.49E-04
W-F25	4/15/14 14:45	398	11460	191.0	8.0	4.34	49570	139633	0.005	0.009	1.54E-04
W-F26	4/15/14 22:49	484	11944	199.1	8.3	4.34	51670	145550	0.011	0.020	1.61E-04
W-F27	4/16/14 9:45	656	12600	210.0	8.8	4.34	54517	153570	0.011	0.020	1.69E-04
W-F28	4/16/14 15:09	324	12924	215.4	9.0	4.34	55923	157531	0.014	0.025	1.74E-04
W-F29	4/16/14 23:10	481	13405	223.4	9.3	4.34	58011	163411	0.018	0.032	1.80E-04
W_F30	4/17/14 8:28	558	13963	232.7	9.7	4.34	60433	170233	0.020	0.036	1.87E-04
W_F31	4/17/14 15:39	431	14394	239.9	10.0	4.34	62303	175502	0.025	0.045	1.93E-04

W_F32	4/17/14 23:20	461	14855	247.6	10.3	4.34	64304	181138	0.026	0.047	1.99E-04
W_F33	4/18/14 8:02	522	15377	256.3	10.7	4.34	66569	187519	0.040	0.072	2.05E-04
W_F34	4/18/14 15:33	451	15828	263.8	11.0	4.34	68527	193033	0.038	0.069	2.11E-04
W_F35	4/18/14 22:07	394	16222	270.4	11.3	4.34	70237	197850	0.042	0.076	2.16E-04
W-F36	4/19/14 8:31	624	16846	280.8	11.7	4.34	72945	205478	0.088	0.159	2.23E-04
W-F37	4/19/14 18:16	585	17431	290.5	12.1	4.34	75484	212630	0.059	0.106	2.30E-04
W-F38	4/19/14 23:26	310	17741	295.7	12.3	4.34	76829	216420	0.061	0.110	2.34E-04
W-F39	4/20/14 7:51	505	18246	304.1	12.7	4.34	79021	222594	0.070	0.126	2.40E-04
W-F41	4/20/14 22:50	899	19145	319.1	13.3	4.34	82923	233585	0.081	0.146	2.50E-04
W-F42	4/21/14 8:18	568	19713	328.5	13.7	4.34	85388	240529	0.085	0.153	2.57E-04
W-F43	4/21/14 17:24	546	20259	337.6	14.1	4.34	87757	247204	0.092	0.166	2.63E-04
W-F44	4/21/14 23:07	343	20602	343.4	14.3	4.34	89246	251397	0.098	0.177	2.67E-04
W-F45	4/22/14 8:32	565	21167	352.8	14.7	4.34	91698	258304	0.107	0.193	2.73E-04
W-F46	4/22/14 14:44	372	21539	359.0	15.0	4.34	93312	262852	0.147	0.265	2.77E-04



Waipahu III - Carbon D, E, F (Run #4)
TCP Concentration (ppb)
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
50000
100000
150000
200000
250000
300000
350000
400000
Bedvolumes
Carbon D
Carbon E
Carbon F

7.2.4 GAC Run #5

Run #5		
Waipahu #3		
Carbon A/B, C, G		
A/B	4.35	mL/min
C	9.67	mL/min
G	4.35	mL/min
Bed Volume	0.355	mL
TCP Influent	0.554	ppb

Sample	TCP Conc. (ppb)
W-Inf1	0.517
W-Inf2	0.536
W-Inf3	0.608
Influent Avg.	0.554

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0055	0.0277	0.0554
A/B	2.642E-04	3.270E-04	3.762E-04
C	7.199E-05	1.196E-04	1.386E-04
G	1.932E-04	2.414E-04	2.813E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0055	0.0277	0.0554
A/B	238763	296847	344999
C	65147	109268	128116
G	174595	219551	258980

Carbon	A/B										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-A/B1	5/1/14 16:11	0	0	0.0	0.0	3.81	0	0	0.000	0.000	0
W-A/B2	5/1/14 22:07	356	356	5.9	0.2	3.81	1356	3821	0.000	0.000	4.23E-06
W-A/B3	5/2/14 8:30	623	979	16.3	0.7	3.81	3730	10507	0.000	0.000	1.16E-05
W-A/B4	5/2/14 16:17	467	1446	24.1	1.0	3.81	5509	15519	0.000	0.000	1.72E-05
W-A/B5	5/2/14 22:54	397	1843	30.7	1.3	4.33	7228	20361	0.000	0.000	2.26E-05
W-A/B6	5/3/14 9:27	633	2476	41.3	1.7	4.29	9944	28011	0.000	0.000	3.10E-05
W-A/B7	5/3/14 17:15	468	2944	49.1	2.0	4.29	11952	33666	0.000	0.000	3.73E-05
W-A/B8	5/3/14 23:11	356	3300	55.0	2.3	4.29	13479	37968	0.000	0.000	4.21E-05
W-A/B9	5/4/14 10:04	653	3953	65.9	2.7	4.30	16287	45878	0.000	0.000	5.08E-05
W-A/B10	5/4/14 16:11	367	4320	72.0	3.0	4.30	17865	50323	0.000	0.000	5.58E-05
W-A/B11	5/4/14 22:13	362	4682	78.0	3.3	4.15	19367	54555	0.000	0.000	6.04E-05
W-A/B12	5/5/14 6:58	525	5207	86.8	3.6	4.15	21546	60693	0.000	0.000	6.72E-05
W-A/B13	5/5/14 14:53	475	5682	94.7	3.9	4.15	23517	66245	0.000	0.000	7.34E-05
W-A/B14	5/6/14 9:49	1136	6818	113.6	4.7	4.15	28232	79525	0.000	0.000	8.81E-05
W-A/B15	5/6/14 16:00	371	7189	119.8	5.0	4.15	29771	83862	0.000	0.000	9.29E-05
W-A/B16	5/6/14 22:30	390	7579	126.3	5.3	4.04	31347	88301	0.000	0.000	9.78E-05
W-A/B17	5/7/14 7:03	513	8092	134.9	5.6	4.04	33419	94139	0.000	0.000	1.04E-04
W-A/B18	5/7/14 18:30	687	8779	146.3	6.1	4.04	36195	101957	0.000	0.000	1.13E-04
W-A/B19	5/7/14 22:38	248	9027	150.5	6.3	4.04	37197	104779	0.000	0.000	1.16E-04
W-A/B20	5/8/14 6:56	498	9525	158.8	6.6	4.04	39209	110447	0.002	0.004	1.22E-04
W-A/B21	5/8/14 17:18	622	10147	169.1	7.0	4.04	41721	117525	0.000	0.000	1.30E-04
W-A/B22	5/9/14 8:37	919	11066	184.4	7.7	4.56	45912	129330	0.000	0.000	1.43E-04
W-A/B23	5/9/14 16:00	443	11509	191.8	8.0	4.56	47932	135020	0.000	0.000	1.50E-04
W-A/B25	5/10/14 11:00	1140	12649	210.8	8.8	4.49	53051	149439	0.000	0.000	1.66E-04
W-A/B26	5/10/14 16:00	300	12949	215.8	9.0	4.49	54398	153233	0.000	0.000	1.70E-04
W-A/B27	5/10/14 23:15	435	13384	223.1	9.3	4.51	56360	158760	0.000	0.000	1.76E-04
W-A/B28	5/11/14 9:53	638	14022	233.7	9.7	4.51	59237	166865	0.000	0.000	1.85E-04
W-A/B29	5/11/14 15:48	355	14377	239.6	10.0	4.51	60838	171375	0.000	0.000	1.90E-04
W-A/B30	5/11/14 23:07	439	14816	246.9	10.3	4.51	62818	176952	0.000	0.000	1.96E-04

W-A/B31	5/12/14 8:00	533	15349	255.8	10.7	4.51	65222	183723	0.000	0.000	2.04E-04
W-A/B32	5/12/14 15:27	447	15796	263.3	11.0	4.51	67238	189402	0.000	0.000	2.10E-04
W-A/B33	5/13/14 0:00	513	16309	271.8	11.3	4.51	69551	195919	0.002	0.004	2.17E-04
W-A/B36	5/13/14 22:17	1337	17646	294.1	12.3	4.51	75581	212905	0.003	0.005	2.36E-04
W-A/B38	5/14/14 14:30	973	18619	310.3	12.9	4.51	79969	225266	0.002	0.004	2.49E-04
W-A/B39	5/14/14 22:11	461	19080	318.0	13.3	4.51	82049	231123	0.003	0.005	2.56E-04
W-A/B40	5/15/14 10:02	711	19791	329.9	13.7	4.51	85255	240156	0.006	0.011	2.66E-04
W-A/B41	5/15/14 16:40	398	20189	336.5	14.0	4.51	87050	245212	0.005	0.009	2.71E-04
W-A/B42	5/15/14 22:14	334	20523	342.0	14.3	4.51	88557	249455	0.010	0.018	2.76E-04
W-A/B43	5/16/14 8:34	620	21143	352.4	14.7	4.51	91353	257332	0.008	0.014	2.85E-04
W-A/B44	5/16/14 15:34	420	21563	359.4	15.0	4.31	93163	262431	0.009	0.016	2.90E-04
W-A/B45	5/17/14 8:10	996	22559	376.0	15.7	4.31	97456	274523	0.013	0.023	3.03E-04
W-A/B46	5/17/14 18:05	595	23154	385.9	16.1	4.36	100050	281831	0.014	0.025	3.11E-04
W-A/B47	5/17/14 23:08	303	23457	390.9	16.3	4.36	101371	285552	0.017	0.031	3.15E-04
W-A/B48	5/18/14 6:36	448	23905	398.4	16.6	4.35	103320	291042	0.019	0.034	3.21E-04
W-A/B49	5/18/14 18:25	709	24614	410.2	17.1	4.35	106404	299729	0.032	0.058	3.30E-04
W-A/B50	5/18/14 23:31	306	24920	415.3	17.3	4.35	107735	303479	0.027	0.049	3.34E-04
W-A/B51	5/19/14 6:33	422	25342	422.4	17.6	4.35	109571	308650	0.033	0.060	3.39E-04
W-A/B52	5/19/14 15:17	524	25866	431.1	18.0	4.35	111850	315071	0.037	0.067	3.46E-04
W-A/B53	5/19/14 22:49	452	26318	438.6	18.3	4.35	113816	320609	0.036	0.065	3.52E-04
W-A/B54	5/20/14 10:11	682	27000	450.0	18.8	4.40	116817	329062	0.051	0.092	3.60E-04
W-A/B55	5/20/14 16:22	371	27371	456.2	19.0	4.40	118450	333661	0.048	0.087	3.65E-04
W-A/B56	5/20/14 22:31	369	27740	462.3	19.3	4.40	120073	338234	0.049	0.088	3.69E-04
W-A/B57	5/21/14 7:12	521	28261	471.0	19.6	4.40	122366	344692	0.055	0.099	3.76E-04
W-A/B58	5/21/14 17:08	596	28857	480.9	20.0	4.40	124988	352079	0.064	0.116	3.83E-04

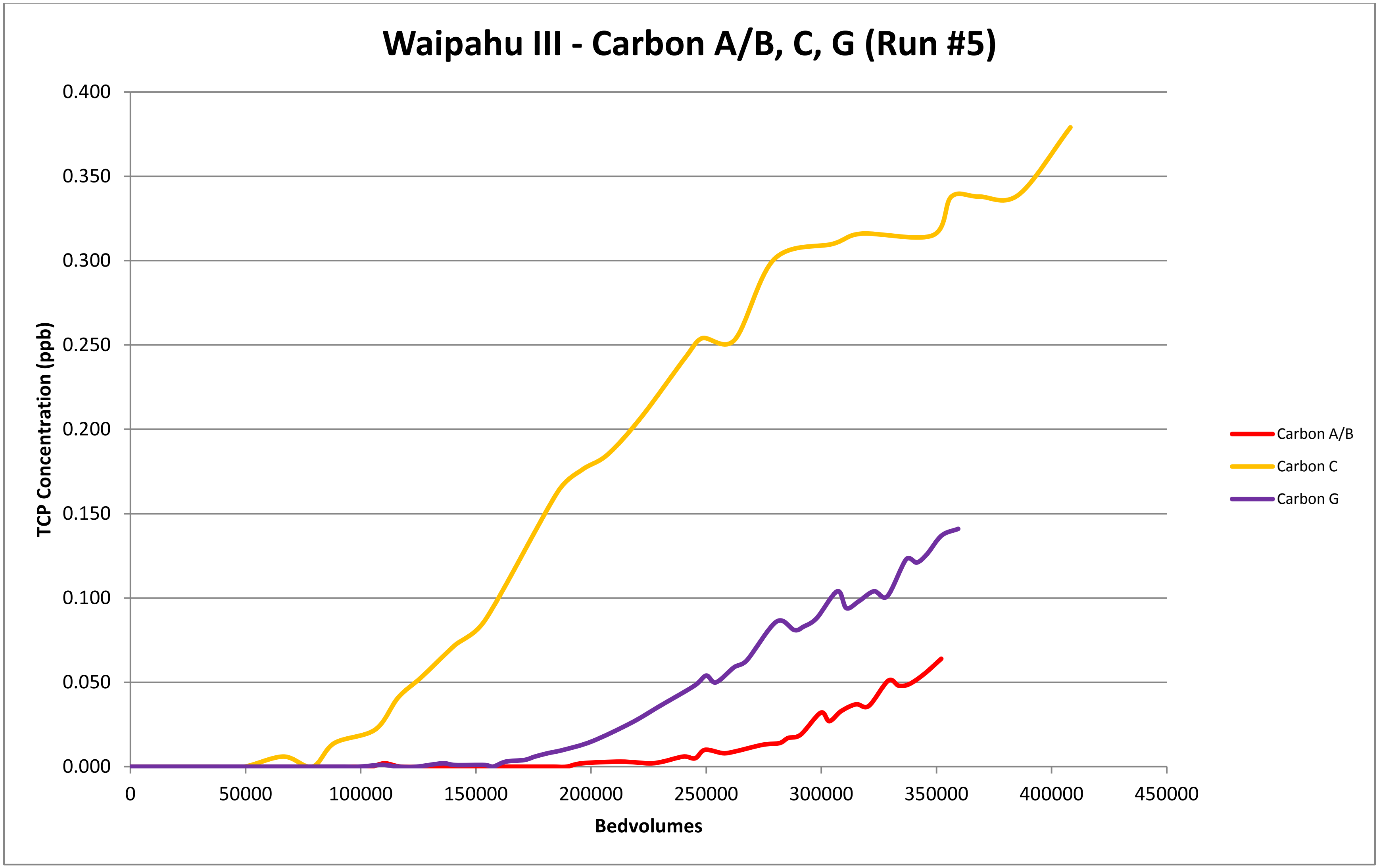
Carbon	C

Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-C1	5/1/14 16:11	0	0	0.0	0.0	9.35	0	0	0.000	0.000	0
W-C2	5/1/14 22:07	356	356	5.9	0.2	9.35	3329	9376	0.000	0.000	1.04E-05
W-C3	5/2/14 8:30	623	979	16.3	0.7	9.35	9154	25785	0.000	0.000	2.86E-05
W-C4	5/2/14 16:17	467	1446	24.1	1.0	9.35	13520	38085	0.000	0.000	4.22E-05
W-C5	5/2/14 22:54	397	1843	30.7	1.3	10.19	17566	49480	0.000	0.000	5.48E-05
W-C6	5/3/14 9:27	633	2476	41.3	1.7	9.52	23592	66455	0.006	0.011	7.34E-05
W-C7	5/3/14 17:15	468	2944	49.1	2.0	9.52	28047	79006	0.000	0.000	8.73E-05
W-C8	5/3/14 23:11	356	3300	55.0	2.3	9.52	31436	88553	0.014	0.025	9.76E-05
W-C9	5/4/14 10:04	653	3953	65.9	2.7	9.64	37731	106285	0.022	0.040	1.17E-04
W-C10	5/4/14 16:11	367	4320	72.0	3.0	9.64	41269	116251	0.041	0.074	1.27E-04
W-C11	5/4/14 22:13	362	4682	78.0	3.3	9.85	44835	126295	0.053	0.096	1.37E-04
W-C12	5/5/14 6:58	525	5207	86.8	3.6	9.85	50006	140862	0.072	0.130	1.51E-04
W-C13	5/5/14 14:53	475	5682	94.7	3.9	9.85	54685	154041	0.087	0.157	1.63E-04
W-C14	5/6/14 9:49	1136	6818	113.6	4.7	9.85	65874	185561	0.163	0.294	1.88E-04
W-C15	5/6/14 16:00	371	7189	119.8	5.0	10.07	69610	196085	0.176	0.318	1.96E-04
W-C16	5/6/14 22:30	390	7579	126.3	5.3	10.07	73538	207148	0.185	0.334	2.04E-04
W-C17	5/7/14 7:03	513	8092	134.9	5.6	10.07	78703	221700	0.207	0.374	2.14E-04
W-C18	5/7/14 18:30	687	8779	146.3	6.1	10.07	85622	241187	0.243	0.439	2.26E-04
W-C19	5/7/14 22:38	248	9027	150.5	6.3	10.07	88119	248222	0.254	0.458	2.30E-04
W-C20	5/8/14 6:56	498	9525	158.8	6.6	10.07	93134	262349	0.253	0.457	2.39E-04
W-C21	5/8/14 17:18	622	10147	169.1	7.0	9.86	99267	279624	0.301	0.543	2.48E-04
W-C22	5/9/14 8:37	919	11066	184.4	7.7	9.86	108328	305149	0.310	0.560	2.60E-04
W-C23	5/9/14 16:00	443	11509	191.8	8.0	9.86	112696	317454	0.316	0.570	2.66E-04
W-C25	5/10/14 11:00	1140	12649	210.8	8.8	9.63	123674	348378	0.315	0.569	2.81E-04
W-C26	5/10/14 16:00	300	12949	215.8	9.0	9.63	126563	356516	0.338	0.610	2.84E-04
W-C27	5/10/14 23:15	435	13384	223.1	9.3	9.63	130752	368316	0.338	0.610	2.89E-04
W-C28	5/11/14 9:53	638	14022	233.7	9.7	9.63	136896	385623	0.339	0.612	2.97E-04
W-C32	5/12/14 15:27	1774	15796	263.3	11.0	4.51	144897	408160	0.379	0.684	3.05E-04

Carbon	G

Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-G1	5/1/14 16:11	0	0	0.0	0.0	4.08	0	0	0.000	0.000	0
W-G2	5/1/14 22:07	356	356	5.9	0.2	4.08	1452	4091	0.000	0.000	4.53E-06
W-G3	5/2/14 8:30	623	979	16.3	0.7	4.08	3994	11252	0.000	0.000	1.25E-05
W-G4	5/2/14 16:17	467	1446	24.1	1.0	4.08	5900	16619	0.000	0.000	1.84E-05
W-G5	5/2/14 22:54	397	1843	30.7	1.3	4.43	7658	21573	0.000	0.000	2.39E-05
W-G6	5/3/14 9:27	633	2476	41.3	1.7	4.50	10507	29597	0.000	0.000	3.28E-05
W-G7	5/3/14 17:15	468	2944	49.1	2.0	4.50	12613	35529	0.000	0.000	3.94E-05
W-G8	5/3/14 23:11	356	3300	55.0	2.3	4.50	14215	40042	0.000	0.000	4.44E-05
W-G9	5/4/14 10:04	653	3953	65.9	2.7	4.48	17140	48283	0.000	0.000	5.35E-05
W-G10	5/4/14 16:11	367	4320	72.0	3.0	4.48	18784	52914	0.000	0.000	5.86E-05
W-G11	5/4/14 22:13	362	4682	78.0	3.3	4.38	20370	57380	0.000	0.000	6.36E-05
W-G12	5/5/14 6:58	525	5207	86.8	3.6	4.38	22670	63858	0.000	0.000	7.08E-05
W-G13	5/5/14 14:53	475	5682	94.7	3.9	4.38	24750	69718	0.000	0.000	7.72E-05
W-G14	5/6/14 9:49	1136	6818	113.6	4.7	4.38	29726	83734	0.000	0.000	9.28E-05
W-G15	5/6/14 16:00	371	7189	119.8	5.0	4.38	31351	88312	0.000	0.000	9.78E-05
W-G16	5/6/14 22:30	390	7579	126.3	5.3	4.31	33032	93047	0.000	0.000	1.03E-04
W-G17	5/7/14 7:03	513	8092	134.9	5.6	4.31	35243	99275	0.000	0.000	1.10E-04
W-G18	5/7/14 18:30	687	8779	146.3	6.1	4.31	38204	107616	0.001	0.002	1.19E-04
W-G19	5/7/14 22:38	248	9027	150.5	6.3	4.31	39272	110627	0.001	0.002	1.23E-04
W-G20	5/8/14 6:56	498	9525	158.8	6.6	4.31	41419	116673	0.000	0.000	1.29E-04
W-G21	5/8/14 17:18	622	10147	169.1	7.0	4.31	44100	124224	0.000	0.000	1.38E-04
W-G22	5/9/14 8:37	919	11066	184.4	7.7	4.35	48097	135485	0.002	0.004	1.50E-04
W-G23	5/9/14 16:00	443	11509	191.8	8.0	4.35	50024	140914	0.001	0.002	1.56E-04
W-G25	5/10/14 11:00	1140	12649	210.8	8.8	4.06	54653	153952	0.001	0.002	1.70E-04
W-G26	5/10/14 16:00	300	12949	215.8	9.0	4.06	55871	157383	0.000	0.000	1.74E-04
W-G27	5/10/14 23:15	435	13384	223.1	9.3	4.54	57846	162946	0.003	0.005	1.80E-04
W-G28	5/11/14 9:53	638	14022	233.7	9.7	4.54	60742	171105	0.004	0.007	1.89E-04
W-G29	5/11/14 15:48	355	14377	239.6	10.0	4.54	62354	175645	0.006	0.011	1.94E-04
W-G30	5/11/14 23:07	439	14816	246.9	10.3	4.54	64347	181259	0.008	0.014	2.00E-04
W-G31	5/12/14 8:00	533	15349	255.8	10.7	4.54	66767	188075	0.010	0.018	2.08E-04
W-G33	5/13/14 0:00	960	16309	271.8	11.3	4.54	71125	200353	0.015	0.027	2.21E-04

W-G36	5/13/14 22:17	1337	17646	294.1	12.3	4.54	77195	217451	0.026	0.047	2.39E-04
W-G38	5/14/14 14:30	973	18619	310.3	12.9	4.54	81613	229895	0.036	0.065	2.52E-04
W-G40	5/15/14 10:02	1172	19791	329.9	13.7	4.54	86933	244883	0.048	0.087	2.67E-04
W-G41	5/15/14 16:40	398	20189	336.5	14.0	4.54	88740	249973	0.054	0.097	2.72E-04
W-G42	5/15/14 22:14	334	20523	342.0	14.3	4.54	90257	254244	0.050	0.090	2.77E-04
W-G43	5/16/14 8:34	620	21143	352.4	14.7	4.54	93072	262173	0.059	0.106	2.84E-04
W-G44	5/16/14 15:34	420	21563	359.4	15.0	4.60	95004	267616	0.063	0.114	2.90E-04
W-G45	5/17/14 8:10	996	22559	376.0	15.7	4.60	99585	280522	0.086	0.155	3.02E-04
W-G46	5/17/14 18:05	595	23154	385.9	16.1	4.64	102346	288298	0.081	0.146	3.09E-04
W-G47	5/17/14 23:08	303	23457	390.9	16.3	4.64	103752	292259	0.083	0.150	3.13E-04
W-G48	5/18/14 6:36	448	23905	398.4	16.6	4.51	105772	297950	0.088	0.159	3.18E-04
W-G49	5/18/14 18:25	709	24614	410.2	17.1	4.51	108970	306958	0.104	0.188	3.26E-04
W-G50	5/18/14 23:31	306	24920	415.3	17.3	4.51	110350	310845	0.094	0.170	3.30E-04
W-G51	5/19/14 6:33	422	25342	422.4	17.6	4.51	112253	316206	0.098	0.177	3.35E-04
W-G52	5/19/14 15:17	524	25866	431.1	18.0	4.51	114616	322863	0.104	0.188	3.41E-04
W-G53	5/19/14 22:49	452	26318	438.6	18.3	4.51	116655	328606	0.101	0.182	3.46E-04
W-G54	5/20/14 10:11	682	27000	450.0	18.8	4.31	119594	336886	0.123	0.222	3.53E-04
W-G55	5/20/14 16:22	371	27371	456.2	19.0	4.31	121193	341390	0.121	0.218	3.57E-04
W-G56	5/20/14 22:31	369	27740	462.3	19.3	4.31	122784	345870	0.126	0.227	3.61E-04
W-G57	5/21/14 7:12	521	28261	471.0	19.6	4.31	125029	352195	0.137	0.247	3.66E-04
W-G58	5/21/14 17:08	596	28857	480.9	20.0	4.31	127598	359431	0.141	0.255	3.72E-04


Waipahu III - Carbon A/B, C, G (Run #5)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
TCP Concentration (ppb)
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
Bedvolumes
Carbon A/B
Carbon C
Carbon G

7.2.5 GAC Run #6

Run #6		
Mililani I		
Carbon A/B, C, D		
A/B	5.10	mL/min
C	11.32	mL/min
D	6.63	mL/min
Bed Volume	0.355	mL
TCP Influent	2.146	ppb

Sample ID	TCP Conc. (ppb)
M-Inf1	2.095
M-Inf2	2.172
M-Inf3	2.171
Influent Avg.	2.146

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.02146	0.1073	0.2146
A/B	6.766E-04	8.743E-04	9.725E-04
C	1.125E-04	3.007E-04	4.261E-04
D	4.211E-04	4.414E-04	4.467E-04

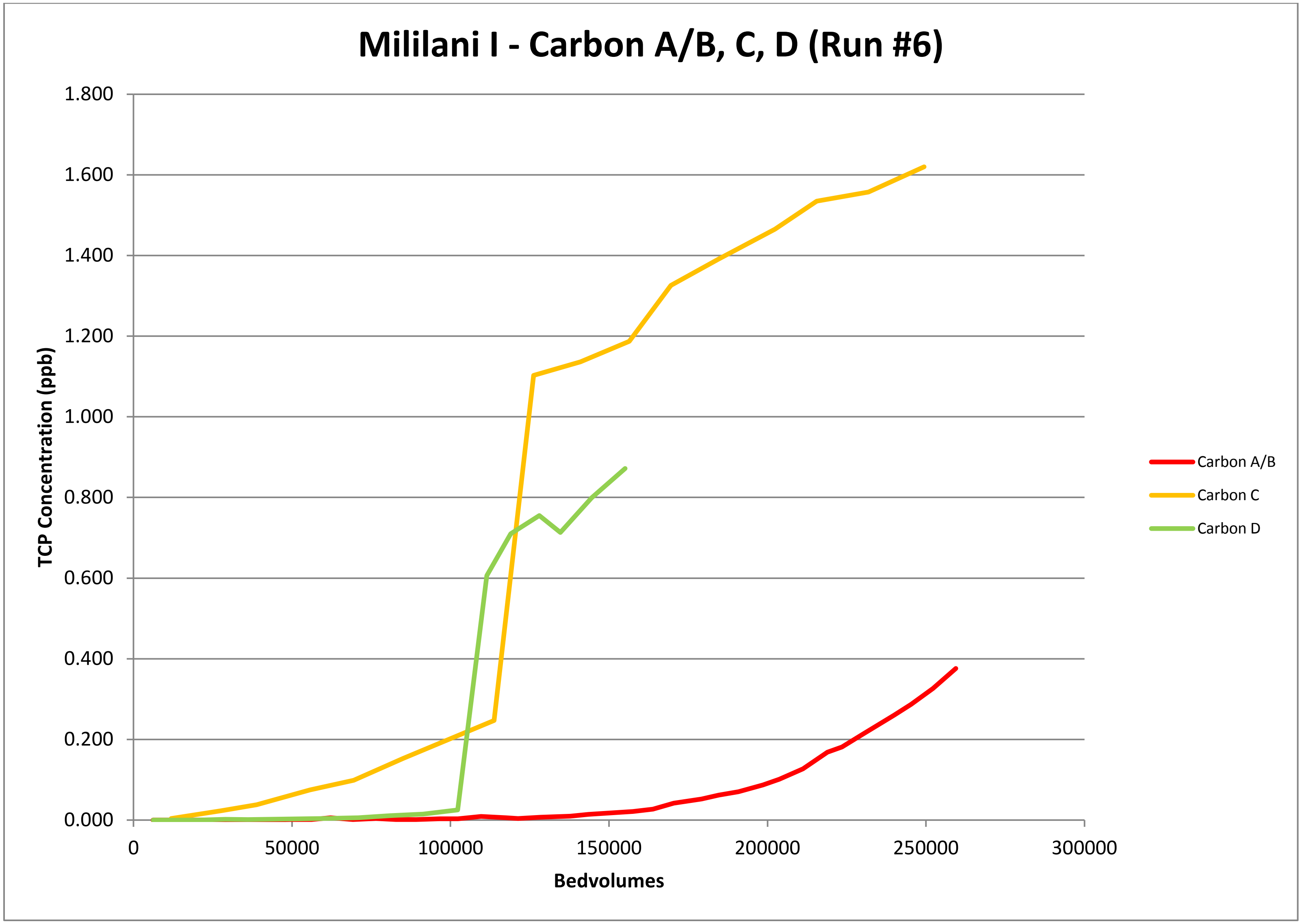
	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.02146	0.1073	0.2146
A/B	158003	205508	230412
C	26395	71843	103852
D	98395	103555	105260

Carbon	A/B										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-1	5/30/14 23:35	395	395	6.6	0.27	5.49	2169	6109	0.000	0.000	2.62E-05
M-2	5/31/14 8:19	524	919	15.3	0.64	5.49	5045	14212	0.000	0.000	6.10E-05
M-3	5/31/14 14:31	372	1291	21.5	0.90	5.49	7088	19965	0.000	0.000	8.57E-05
M-4	5/31/14 23:49	558	1849	30.8	1.28	5.49	10151	28594	0.000	0.000	1.23E-04
M-6	6/1/14 16:00	971	2820	47.0	1.96	5.11	15113	42571	0.000	0.000	1.83E-04
M-7	6/2/14 0:13	493	3313	55.2	2.30	4.91	17533	49390	0.001	0.000	2.12E-04
M-8	6/2/14 8:25	492	3805	63.4	2.64	4.91	19949	56195	0.001	0.000	2.41E-04
M-9	6/2/14 15:34	429	4234	70.6	2.94	4.91	22056	62128	0.006	0.003	2.67E-04
M-10	6/2/14 23:55	501	4735	78.9	3.29	4.99	24556	69171	0.001	0.000	2.97E-04
M-11	6/3/14 8:37	522	5257	87.6	3.65	4.99	27160	76508	0.004	0.002	3.28E-04
M-12	6/3/14 16:00	443	5700	95.0	3.96	4.99	29371	82735	0.001	0.000	3.55E-04
M-13	6/3/14 23:30	450	6150	102.5	4.27	5.05	31643	89136	0.001	0.000	3.82E-04
M-14	6/4/14 8:23	533	6683	111.4	4.64	5.05	34335	96718	0.003	0.001	4.15E-04
M-15	6/4/14 15:00	397	7080	118.0	4.92	5.05	36340	102366	0.003	0.001	4.39E-04
M-16	6/4/14 23:30	510	7590	126.5	5.27	5.08	38931	109664	0.009	0.004	4.70E-04
M-17	6/5/14 8:40	550	8140	135.7	5.65	5.08	41725	117534	0.006	0.003	5.04E-04
M-18	6/5/14 13:05	265	8405	140.1	5.84	4.99	43047	121259	0.004	0.002	5.20E-04
M-19	6/5/14 21:35	510	8915	148.6	6.19	4.99	45592	128428	0.007	0.003	5.51E-04
M-20	6/6/14 8:40	665	9580	159.7	6.65	5.00	48917	137794	0.010	0.005	5.91E-04
M-21	6/6/14 15:25	405	9985	166.4	6.93	5.00	50942	143498	0.014	0.007	6.15E-04
M-23	6/7/14 8:00	995	10980	183.0	7.63	5.00	55917	157513	0.021	0.010	6.74E-04
M-24	6/7/14 15:34	454	11434	190.6	7.94	5.00	58187	163907	0.027	0.013	7.02E-04
M-25	6/7/14 23:15	461	11895	198.2	8.26	5.00	60492	170400	0.042	0.020	7.29E-04
M-26	6/8/14 9:41	626	12521	208.7	8.70	5.00	63622	179217	0.052	0.024	7.66E-04
M-27	6/8/14 16:02	381	12902	215.0	8.96	5.00	65527	184583	0.062	0.029	7.88E-04
M-28	6/8/14 23:30	448	13350	222.5	9.27	5.00	67767	190893	0.070	0.033	8.14E-04
M-29	6/9/14 8:37	547	13897	231.6	9.65	5.00	70502	198597	0.087	0.041	8.46E-04
M-30	6/9/14 14:39	362	14259	237.7	9.90	5.00	72312	203696	0.101	0.047	8.67E-04
M-31	6/9/14 23:30	531	14790	246.5	10.27	5.00	74967	211175	0.127	0.059	8.97E-04

M-32	6/10/14 8:37	547	15337	255.6	10.65	5.00	77702	218879	0.168	0.078	9.28E-04
M-33	6/10/14 14:07	330	15667	261.1	10.88	5.00	79352	223527	0.181	0.084	9.46E-04
M-34	6/10/14 22:07	480	16147	269.1	11.21	5.00	81752	230287	0.214	0.100	9.72E-04
M-35	6/11/14 9:28	681	16828	280.5	11.69	5.00	85157	239879	0.260	0.121	1.01E-03
M-36	6/11/14 15:54	386	17214	286.9	11.95	5.00	87087	245315	0.287	0.134	1.03E-03
M-37	6/12/14 0:05	491	17705	295.1	12.30	5.00	89542	252231	0.326	0.152	1.05E-03
M-38	6/12/14 8:35	510	18215	303.6	12.65	5.00	92092	259414	0.376	0.175	1.08E-03

Carbon	C										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-1	5/30/14 23:35	395	395	6.6	0.27	10.69	4223	11895	0.004	0.002	5.10E-05
M-2	5/31/14 8:19	524	919	15.3	0.64	10.69	9824	27674	0.023	0.011	1.18E-04
M-3	5/31/14 14:31	372	1291	21.5	0.90	10.69	13801	38875	0.038	0.018	1.65E-04
M-4	5/31/14 23:49	558	1849	30.8	1.28	10.69	19766	55678	0.075	0.035	2.35E-04
M-5	6/1/14 7:26	457	2306	38.4	1.60	10.69	24651	69440	0.099	0.046	2.91E-04
M-6	6/1/14 16:00	514	2820	47.0	1.96	10.80	30202	85077	0.153	0.071	3.53E-04
M-7	6/2/14 0:13	493	3313	55.2	2.30	10.32	35290	99409	0.2	0.093	4.09E-04
M-8	6/2/14 8:25	492	3805	63.4	2.64	10.32	40368	113711	0.247	0.115	4.64E-04
M-9	6/2/14 15:34	429	4234	70.6	2.94	10.32	44795	126183	1.103	0.514	4.90E-04
M-10	6/2/14 23:55	501	4735	78.9	3.29	10.50	50055	141001	1.136	0.529	5.19E-04
M-11	6/3/14 8:37	522	5257	87.6	3.65	10.50	55536	156440	1.187	0.553	5.49E-04
M-12	6/3/14 16:00	443	5700	95.0	3.96	10.50	60188	169543	1.326	0.618	5.71E-04
M-13	6/3/14 23:30	450	6150	102.5	4.27	11.84	65516	184552	1.391	0.648	5.93E-04
M-14	6/4/14 8:23	533	6683	111.4	4.64	11.84	71827	202328	1.465	0.683	6.17E-04
M-15	6/4/14 15:00	397	7080	118.0	4.92	11.84	76527	215569	1.535	0.715	6.34E-04
M-16	6/4/14 23:30	510	7590	126.5	5.27	11.33	82305	231846	1.557	0.726	6.53E-04
M-17	6/5/14 8:40	550	8140	135.7	5.65	11.33	88537	249399	1.62	0.755	6.71E-04

Carbon	D										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-1	5/30/14 23:35	395	395	6.6	0.27	5.56	2196	6186	0.000	0.000	2.66E-05
M-2	5/31/14 8:19	524	919	15.3	0.64	5.56	5110	14393	0.000	0.000	6.18E-05
M-3	5/31/14 14:31	372	1291	21.5	0.90	5.56	7178	20220	0.000	0.000	8.68E-05
M-4	5/31/14 23:49	558	1849	30.8	1.28	5.56	10280	28959	0.002	0.001	1.24E-04
M-5	6/1/14 7:26	457	2306	38.4	1.60	5.56	12821	36117	0.001	0.000	1.55E-04
M-7	6/2/14 0:13	1007	3313	55.2	2.30	8.25	21129	59519	0.004	0.002	2.55E-04
M-8	6/2/14 8:25	492	3805	63.4	2.64	8.25	25188	70952	0.006	0.003	3.04E-04
M-9	6/2/14 15:34	429	4234	70.6	2.94	8.25	28727	80922	0.011	0.005	3.47E-04
M-10	6/2/14 23:55	501	4735	78.9	3.29	7.40	32435	91366	0.015	0.007	3.91E-04
M-11	6/3/14 8:37	522	5257	87.6	3.65	7.40	36298	102247	0.025	0.012	4.37E-04
M-12	6/3/14 16:00	443	5700	95.0	3.96	7.40	39576	111481	0.606	0.282	4.66E-04
M-13	6/3/14 23:30	450	6150	102.5	4.27	5.96	42258	119036	0.71	0.331	4.88E-04
M-14	6/4/14 8:23	533	6683	111.4	4.64	5.96	45434	127984	0.755	0.352	5.12E-04
M-15	6/4/14 15:00	397	7080	118.0	4.92	5.96	47801	134649	0.713	0.332	5.32E-04
M-16	6/4/14 23:30	510	7590	126.5	5.27	6.84	51289	144476	0.799	0.372	5.58E-04
M-17	6/5/14 8:40	550	8140	135.7	5.65	6.84	55051	155073	0.872	0.406	5.85E-04



Mililani I - Carbon A/B, C, D (Run #6)
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
TCP Concentration (ppb)
0
50000
100000
150000
200000
250000
300000
Bedvolumes
Carbon A/B
Carbon C
Carbon D

7.2.6 GAC Run #7

Run #7		
Mililani I		
Carbon E, F, G		
E	6.63	mL/min
F	5.10	mL/min
G	5.10	mL/min
Bed Volume	0.355	mL
TCP Influent	2.298	ppb

Sample ID	TCP Conc. (ppb)
M-Infl1	2.299
M-Infl2	2.308
M-Infl3	2.286
Influent Avg.	2.298

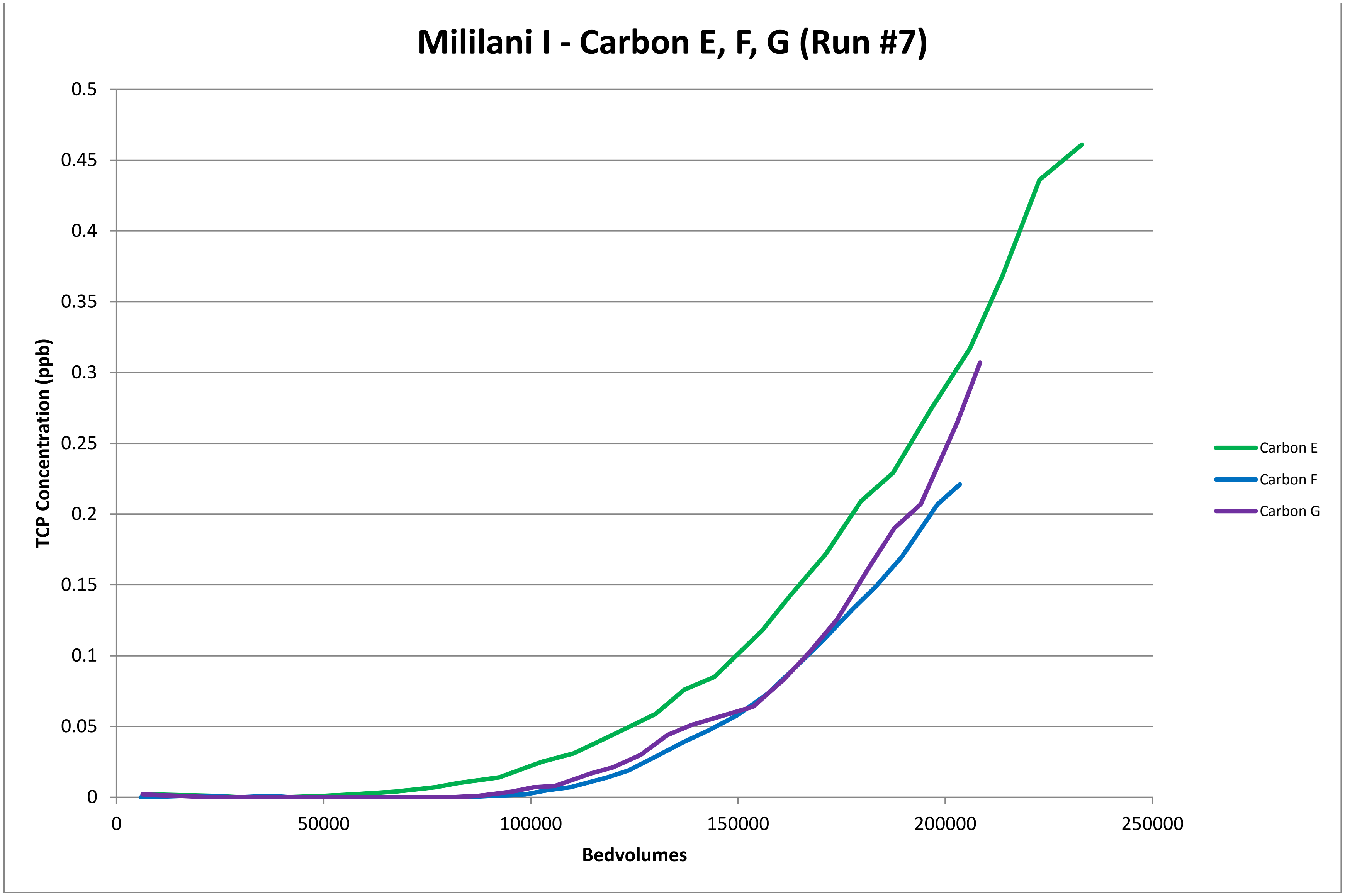
	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	2.298E-02	1.149E-01	2.298E-01
E	4.619E-04	7.026E-04	8.407E-04
F	5.794E-04	7.824E-04	9.279E-04
G	5.735E-04	7.602E-04	8.730E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0230	0.1149	0.2298
E	100757	154737.8	187474.8
F	126272	171791	206857.5
G	121200	170807.1	197541.8

Carbon	E										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-E1	6/16/14 20:50	395	395	6.6	0.27	7.31	2887	8134	0.002	0.001	3.73E-05
M-E2	6/17/14 8:47	717	1112	18.5	0.77	7.31	8129	22898	0.001	0.000	1.05E-04
M-E3	6/17/14 14:55	368	1480	24.7	1.03	7.31	10819	30475	0	0.000	1.40E-04
M-E4	6/17/14 23:40	525	2005	33.4	1.39	6.56	14263	40177	0	0.000	1.85E-04
M-E5	6/18/14 8:47	547	2552	42.5	1.77	6.56	17851	50285	0.001	0.000	2.31E-04
M-E6	6/18/14 14:52	365	2917	48.6	2.03	6.56	20246	57030	0.002	0.001	2.62E-04
M-E7	6/19/14 0:05	553	3470	57.8	2.41	6.55	23868	67233	0.004	0.002	3.09E-04
M-E8	6/19/14 8:52	527	3997	66.6	2.78	6.55	27320	76956	0.007	0.003	3.53E-04
M-E9	6/19/14 13:51	299	4296	71.6	2.98	6.55	29278	82473	0.01	0.004	3.79E-04
M-E10	6/19/14 23:00	549	4845	80.8	3.36	6.4	32792	92371	0.014	0.006	4.24E-04
M-E11	6/20/14 8:30	570	5415	90.2	3.76	6.4	36440	102647	0.025	0.011	4.70E-04
M-E12	6/20/14 15:36	426	5841	97.4	4.06	6.4	39166	110327	0.031	0.013	5.05E-04
M-E13	6/21/14 0:12	516	6357	105.9	4.41	6.4	42468	119629	0.044	0.019	5.47E-04
M-E14	6/21/14 9:55	583	6940	115.7	4.82	6.4	46200	130140	0.059	0.026	5.94E-04
M-E15	6/21/14 16:19	384	7324	122.1	5.09	6.4	48657	137062	0.076	0.033	6.25E-04
M-E16	6/21/14 23:01	402	7726	128.8	5.37	6.34	51206	144242	0.085	0.037	6.57E-04
M-E17	6/22/14 9:50	649	8375	139.6	5.82	6.34	55321	155832	0.118	0.051	7.07E-04
M-E18	6/22/14 16:00	370	8745	145.7	6.07	6.34	57666	162440	0.142	0.062	7.36E-04
M-E19	6/23/14 0:12	492	9237	153.9	6.41	6.34	60786	171227	0.172	0.075	7.73E-04
M-E20	6/23/14 8:03	471	9708	161.8	6.74	6.34	63772	179639	0.209	0.091	8.08E-04
M-E21	6/23/14 15:13	430	10138	169.0	7.04	6.34	66498	187318	0.229	0.100	8.40E-04
M-E22	6/23/14 23:27	494	10632	177.2	7.38	6.61	69763	196516	0.274	0.119	8.77E-04
M-E23	6/24/14 7:52	505	11137	185.6	7.73	6.61	73101	205919	0.317	0.138	9.15E-04
M-E24	6/24/14 15:00	428	11565	192.8	8.03	6.61	75930	213888	0.369	0.161	9.45E-04
M-E25	6/24/14 22:55	475	12040	200.7	8.36	6.61	79070	222733	0.436	0.190	9.78E-04
M-E26	6/25/14 8:05	550	12590	209.8	8.74	6.61	82706	232974	0.461	0.201	1.02E-03

Carbon	F										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-F1	6/16/14 20:50	395	395	6.6	0.27	5.25	2074	5842	0	0.000	2.68E-05
M-F2	6/17/14 8:47	717	1112	18.5	0.77	5.25	5838	16445	0.001	0.000	7.55E-05
M-F3	6/17/14 14:55	368	1480	24.7	1.03	5.25	7770	21887	0.001	0.000	1.01E-04
M-F4	6/17/14 23:40	525	2005	33.4	1.39	5.04	10416	29341	0	0.000	1.35E-04
M-F5	6/18/14 8:47	547	2552	42.5	1.77	5.04	13173	37107	0.001	0.000	1.70E-04
M-F6	6/18/14 14:52	365	2917	48.6	2.03	5.04	15012	42289	0	0.000	1.94E-04
M-F7	6/19/14 0:05	553	3470	57.8	2.41	5.04	17800	50140	0	0.000	2.30E-04
M-F8	6/19/14 8:52	527	3997	66.6	2.78	5.04	20456	57622	0.000	0.000	2.65E-04
M-F9	6/19/14 13:51	299	4296	71.6	2.98	5.04	21963	61867	0.000	0.000	2.84E-04
M-F10	6/19/14 23:00	549	4845	80.8	3.36	4.94	24675	69506	0.000	0.000	3.19E-04
M-F11	6/20/14 8:30	570	5415	90.2	3.76	4.94	27490	77438	0.000	0.000	3.56E-04
M-F12	6/20/14 15:36	426	5841	97.4	4.06	4.94	29595	83366	0.000	0.000	3.83E-04
M-F13	6/21/14 0:12	516	6357	105.9	4.41	4.94	32144	90546	0.001	0.000	4.16E-04
M-F14	6/21/14 9:55	583	6940	115.7	4.82	4.94	35024	98659	0.002	0.001	4.53E-04
M-F15	6/21/14 16:19	384	7324	122.1	5.09	4.94	36921	104003	0.005	0.002	4.78E-04
M-F16	6/21/14 23:01	402	7726	128.8	5.37	4.89	38887	109540	0.007	0.003	5.03E-04
M-F17	6/22/14 9:50	649	8375	139.6	5.82	4.89	42060	118480	0.014	0.006	5.44E-04
M-F18	6/22/14 16:00	370	8745	145.7	6.07	4.89	43870	123576	0.019	0.008	5.67E-04
M-F19	6/23/14 0:12	492	9237	153.9	6.41	4.89	46276	130354	0.029	0.013	5.98E-04
M-F20	6/23/14 8:03	471	9708	161.8	6.74	4.89	48579	136841	0.039	0.017	6.27E-04
M-F21	6/23/14 15:13	430	10138	169.0	7.04	4.89	50681	142765	0.047	0.020	6.54E-04
M-F22	6/23/14 23:27	494	10632	177.2	7.38	5.08	53191	149834	0.058	0.025	6.86E-04
M-F23	6/24/14 7:52	505	11137	185.6	7.73	5.08	55756	157060	0.073	0.032	7.18E-04
M-F24	6/24/14 15:00	428	11565	192.8	8.03	5.08	57931	163185	0.09	0.039	7.45E-04
M-F25	6/24/14 22:55	475	12040	200.7	8.36	5.01	60310	169888	0.109	0.047	7.74E-04
M-F26	6/25/14 8:05	550	12590	209.8	8.74	5.01	63066	177650	0.133	0.058	8.08E-04
M-F27	6/25/14 14:44	399	12989	216.5	9.02	5.01	65065	183281	0.149	0.065	8.32E-04
M-F28	6/25/14 22:06	442	13431	223.8	9.33	5.01	67279	189519	0.17	0.074	8.58E-04
M-F29	6/26/14 8:15	609	14040	234.0	9.75	5.01	70330	198114	0.207	0.090	8.94E-04
M-F30	6/26/14 14:36	381	14421	240.3	10.01	5.01	72239	203491	0.221	0.096	9.17E-04

Carbon	G										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-G1	6/16/14 20:50	395	395	6.6	0.27	5.62	2220	6253	0.002	0.001	2.87E-05
M-G3	6/17/14 14:55	1085	1480	24.7	1.03	5.62	8318	23430	0	0.000	1.08E-04
M-G4	6/17/14 23:40	525	2005	33.4	1.39	4.77	9564	26940	0	0.000	1.40E-04
M-G5	6/18/14 8:47	547	2552	42.5	1.77	4.77	12173	34290	0	0.000	1.74E-04
M-G6	6/18/14 14:52	365	2917	48.6	2.03	4.77	13914	39195	0	0.000	1.96E-04
M-G7	6/19/14 0:05	553	3470	57.8	2.41	5.07	17593	49557	0	0.000	2.33E-04
M-G8	6/19/14 8:52	527	3997	66.6	2.78	5.07	20265	57084	0.000	0.000	2.67E-04
M-G9	6/19/14 13:51	299	4296	71.6	2.98	5.07	21781	61354	0.000	0.000	2.87E-04
M-G10	6/19/14 23:00	549	4845	80.8	3.36	4.88	23644	66602	0.000	0.000	3.22E-04
M-G11	6/20/14 8:30	570	5415	90.2	3.76	4.88	26425	74437	0.000	0.000	3.58E-04
M-G12	6/20/14 15:36	426	5841	97.4	4.06	4.88	28504	80293	0.000	0.000	3.84E-04
M-G13	6/21/14 0:12	516	6357	105.9	4.41	4.88	31022	87386	0.001	0.000	4.17E-04
M-G14	6/21/14 9:55	583	6940	115.7	4.82	4.88	33867	95401	0.004	0.002	4.54E-04
M-G15	6/21/14 16:19	384	7324	122.1	5.09	4.88	35741	100679	0.007	0.003	4.78E-04
M-G16	6/21/14 23:01	402	7726	128.8	5.37	4.86	37548	105770	0.008	0.003	5.03E-04
M-G17	6/22/14 9:50	649	8375	139.6	5.82	4.86	40702	114655	0.017	0.007	5.44E-04
M-G18	6/22/14 16:00	370	8745	145.7	6.07	4.86	42501	119720	0.021	0.009	5.67E-04
M-G19	6/23/14 0:12	492	9237	153.9	6.41	4.86	44892	126456	0.03	0.013	5.97E-04
M-G20	6/23/14 8:03	471	9708	161.8	6.74	4.86	47181	132904	0.044	0.019	6.26E-04
M-G21	6/23/14 15:13	430	10138	169.0	7.04	4.86	49271	138791	0.051	0.022	6.53E-04
M-G22	6/23/14 23:27	494	10632	177.2	7.38	5.13	54542	153640	0.064	0.028	6.85E-04
M-G23	6/24/14 7:52	505	11137	185.6	7.73	5.13	57133	160937	0.083	0.036	7.17E-04
M-G24	6/24/14 15:00	428	11565	192.8	8.03	5.13	59328	167122	0.102	0.044	7.44E-04
M-G25	6/24/14 22:55	475	12040	200.7	8.36	5.13	61765	173986	0.126	0.055	7.74E-04
M-G26	6/25/14 8:05	550	12590	209.8	8.74	5.13	64587	181934	0.164	0.071	8.08E-04
M-G27	6/25/14 14:44	399	12989	216.5	9.02	5.13	66634	187700	0.19	0.083	8.32E-04
M-G28	6/25/14 22:06	442	13431	223.8	9.33	5.13	68901	194087	0.207	0.090	8.59E-04
M-G29	6/26/14 8:15	609	14040	234.0	9.75	5.13	72025	202888	0.265	0.115	8.95E-04
M-G30	6/26/14 14:36	381	14421	240.3	10.01	5.13	73980	208394	0.307	0.134	9.17E-04



Mililani I - Carbon E, F, G (Run #7)
TCP Concentration (ppb)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50000
100000
150000
200000
250000
Bedvolumes
Carbon E
Carbon F
Carbon G

7.2.7 GAC Run #8

Run #8		
Kunia I		
Carbon D, F, G		
D	6.63	mL/min
F	5.10	mL/min
G	5.10	mL/min
Bed Volume	0.355	mL
TCP Influent	0.803	ppb

Sample ID	TCP Conc. (ppb)
K-Infl1	0.800
K-Infl2	0.805
Influent Avg.	0.803

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru	5% Breakthru (ppb)	10% Breakthru
Limit Conc. (ppb)	0.0080	0.0401	0.0803
D	2.583E-04	3.369E-04	3.818E-04
F	1.443E-04	2.156E-04	2.533E-04
G	8.854E-05	1.583E-04	2.328E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0080	0.0401	0.0803
D	164224	214707	245779
F	90183	135942	161667
G	55465	100264	150391

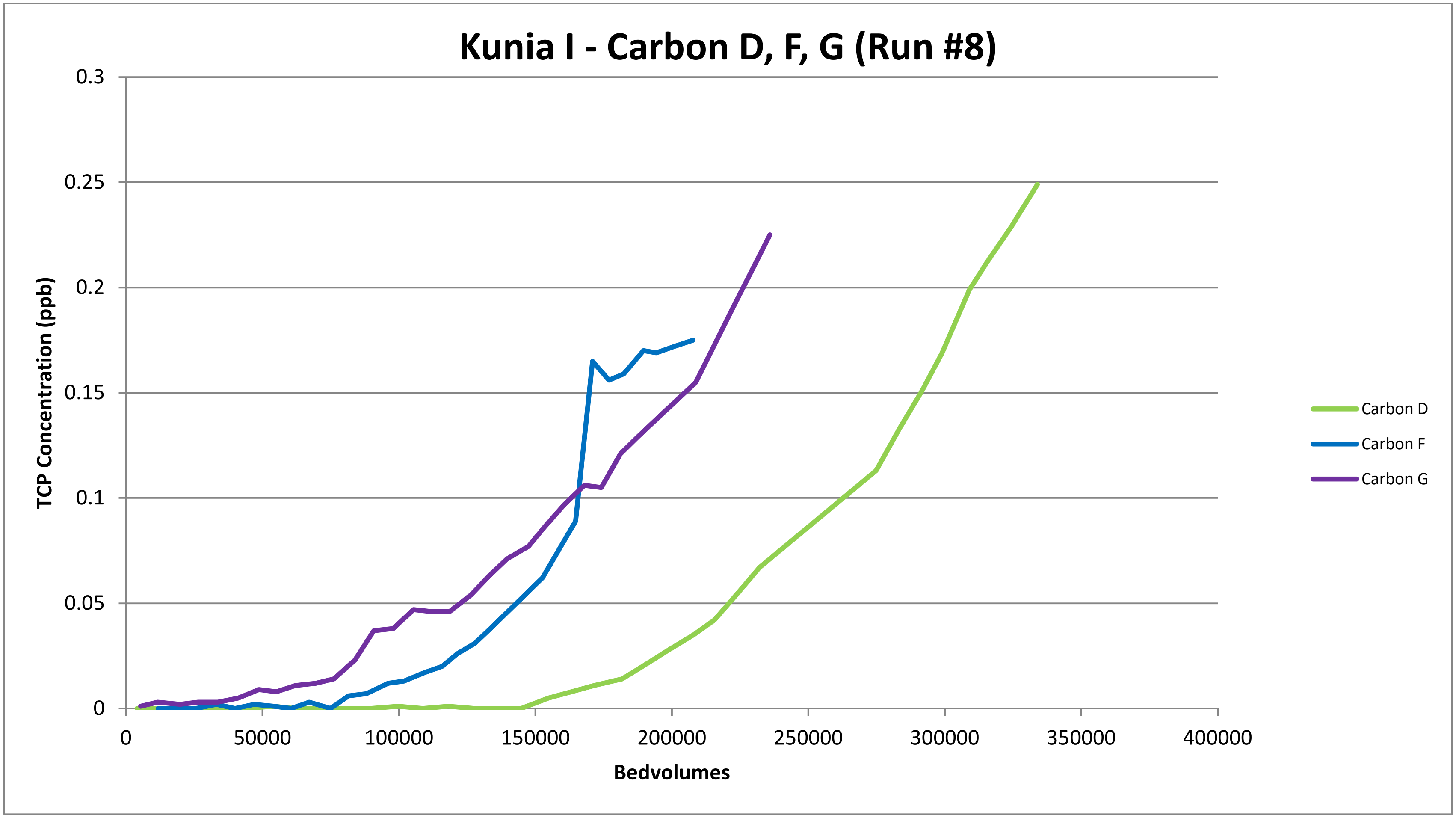
Carbon	D										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-D1	7/10/14 15:30	90	395	6.6	0.27	3.64	1438	4050	0	0.000	1.48E-06
M-D2	7/10/14 23:20	470	865	14.4	0.60	3.64	3149	8869	0	0.000	9.22E-06
M-D3	7/11/14 8:00	520	1385	23.1	0.96	4.91	5702	16061	0	0.000	2.08E-05
M-D4	7/11/14 15:30	450	1835	30.6	1.27	6.92	8816	24833	0	0.000	3.48E-05
M-D5	7/11/14 23:37	487	2322	38.7	1.61	6.92	12186	34326	0	0.000	5.01E-05
M-D6	7/12/14 8:00	503	2825	47.1	1.96	6.92	15667	44131	0	0.000	6.58E-05
M-D7	7/12/14 16:30	510	3335	55.6	2.32	6.92	19196	54073	0.001	0.001	8.17E-05
M-D8	7/12/14 23:40	430	3765	62.7	2.61	6.92	22171	62455	0	0.000	9.52E-05
M-D9	7/13/14 7:30	470	4235	70.6	2.94	6.92	25424	71616	0	0.000	1.10E-04
M-D10	7/13/14 15:50	500	4735	78.9	3.29	6.92	28884	81363	0	0.000	1.26E-04
M-D11	7/13/14 23:20	450	5185	86.4	3.60	6.92	31998	90135	0	0.000	1.40E-04
M-D12	7/14/14 8:00	520	5705	95.1	3.96	6.92	35596	100271	0.001	0.001	1.56E-04
M-D13	7/14/14 15:45	465	6170	102.8	4.28	6.92	38814	109335	0	0.000	1.70E-04
M-D14	7/14/14 23:47	482	6652	110.9	4.62	6.92	42149	118731	0.001	0.001	1.85E-04
M-D15	7/15/14 8:05	498	7150	119.2	4.97	6.92	45596	128438	0	0.000	2.01E-04
M-D16	7/15/14 15:20	435	7585	126.4	5.27	6.92	48606	136918	0	0.000	2.15E-04
M-D17	7/15/14 23:00	460	8045	134.1	5.59	6.65	51665	145535	0	0.000	2.29E-04
M-D18	7/16/14 8:00	540	8585	143.1	5.96	6.65	55256	155650	0.005	0.006	2.45E-04
M-D19	7/16/14 15:34	454	9039	150.6	6.28	6.65	58275	164155	0.008	0.010	2.58E-04
M-D20	7/16/14 23:00	446	9485	158.1	6.59	6.65	61241	172509	0.011	0.014	2.71E-04
M-D21	7/17/14 8:15	555	10040	167.3	6.97	6.6	64904	182828	0.014	0.017	2.88E-04
M-D22	7/17/14 15:00	405	10445	174.1	7.25	6.6	67577	190357	0.02	0.025	2.99E-04
M-D23	7/17/14 23:48	528	10973	182.9	7.62	6.6	71062	200174	0.028	0.035	3.15E-04
M-D24	7/18/14 8:15	507	11480	191.3	7.97	6.25	74230	209100	0.035	0.044	3.28E-04
M-D25	7/18/14 15:30	435	11915	198.6	8.27	6.25	76949	216758	0.042	0.052	3.40E-04
M-D26	7/18/14 23:50	500	12415	206.9	8.62	6.25	80074	225561	0.055	0.069	3.53E-04
M-D27	7/19/14 7:15	445	12860	214.3	8.93	6.25	82855	233395	0.067	0.083	3.65E-04
M-D32	7/20/14 23:57	2442	15302	255.0	10.63	6.25	98118	276388	0.113	0.141	4.24E-04
M-D33	7/21/14 8:05	488	15790	263.2	10.97	6.25	101168	284980	0.133	0.166	4.35E-04

M-D34	7/21/14 16:00	475	16265	271.1	11.30	6.25	104137	293343	0.151	0.188	4.46E-04
M-D35	7/21/14 23:00	420	16685	278.1	11.59	6.25	106762	300737	0.169	0.211	4.56E-04
M-D36	7/22/14 8:29	569	17254	287.6	11.98	6.25	110318	310755	0.199	0.248	4.68E-04
M-D37	7/22/14 14:39	370	17624	293.7	12.24	6.25	112630	317269	0.212	0.264	4.76E-04
M-D38	7/22/14 23:05	506	18130	302.2	12.59	6.25	115793	326177	0.229	0.285	4.86E-04
M-D39	7/23/14 8:09	544	18674	311.2	12.97	6.25	119193	335755	0.249	0.310	4.96E-04

Carbon	F										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-F9	7/13/14 7:30	810	810	13.5	0.56	5.19	4204	11842	0.000	0.000	1.90E-05
M-F10	7/13/14 15:50	500	1310	21.8	0.91	5.19	6799	19152	0.000	0.000	3.07E-05
M-F11	7/13/14 23:20	450	1760	29.3	1.22	5.19	9134	25731	0.000	0.000	4.13E-05
M-F12	7/14/14 8:00	520	2280	38.0	1.58	5.19	11833	33333	0.002	0.002	5.35E-05
M-F13	7/14/14 15:45	465	2745	45.8	1.91	5.19	14247	40131	0.000	0.000	6.44E-05
M-F14	7/14/14 23:47	482	3227	53.8	2.24	5.19	16748	47178	0.002	0.002	7.57E-05
M-F15	7/15/14 8:05	498	3725	62.1	2.59	5.19	19333	54458	0.001	0.001	8.73E-05
M-F16	7/15/14 15:20	435	4160	69.3	2.89	5.19	21590	60818	0.000	0.000	9.75E-05
M-F17	7/15/14 23:00	460	4620	77.0	3.21	5.18	23973	67530	0.003	0.004	1.08E-04
M-F19	7/16/14 15:34	994	5614	93.6	3.90	5.18	29122	82034	0.006	0.007	1.31E-04
M-F20	7/16/14 23:00	446	6060	101.0	4.21	5.18	31432	88542	0.007	0.009	1.42E-04
M-F21	7/17/14 8:15	555	6615	110.3	4.59	5.12	34274	96546	0.012	0.015	1.54E-04
M-F22	7/17/14 15:00	405	7020	117.0	4.88	5.12	36348	102388	0.013	0.016	1.64E-04
M-F23	7/17/14 23:48	528	7548	125.8	5.24	5.12	39051	110003	0.017	0.021	1.76E-04
M-F24	7/18/14 8:15	507	8055	134.3	5.59	4.56	41363	116515	0.020	0.025	1.86E-04
M-F25	7/18/14 15:30	435	8490	141.5	5.90	4.56	43346	122103	0.026	0.032	1.94E-04
M-F26	7/18/14 23:50	500	8990	149.8	6.24	4.56	45626	128525	0.031	0.039	2.04E-04
M-F27	7/19/14 7:15	445	9435	157.3	6.55	4.56	47656	134241	0.038	0.047	2.13E-04
M-F30	7/20/14 8:10	1495	10930	182.2	7.59	4.56	54473	153445	0.062	0.077	2.42E-04
M-F32	7/20/14 23:57	947	11877	198.0	8.25	4.56	58791	165609	0.089	0.111	2.59E-04
M-F33	7/21/14 8:05	488	12365	206.1	8.59	4.56	61016	171877	0.165	0.206	2.67E-04
M-F34	7/21/14 16:00	475	12840	214.0	8.92	4.56	63182	177979	0.156	0.194	2.75E-04
M-F35	7/21/14 23:00	420	13260	221.0	9.21	4.56	65098	183374	0.159	0.198	2.82E-04
M-F36	7/22/14 8:29	569	13829	230.5	9.60	4.56	67692	190683	0.170	0.212	2.91E-04
M-F37	7/22/14 14:39	370	14199	236.7	9.86	4.56	69380	195435	0.169	0.211	2.97E-04
M-F38	7/22/14 23:05	506	14705	245.1	10.21	4.56	71687	201935	0.172	0.214	3.05E-04
M-F39	7/23/14 8:09	544	15249	254.2	10.59	4.56	74168	208923	0.175	0.218	3.14E-04

Carbon	G

Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
M-G1	7/10/14 15:30	395	395	6.6	0.27	4.79	1892	5330	0.001	0.001	8.54E-06
M-G2	7/10/14 23:20	470	865	14.4	0.60	4.79	4143	11671	0.003	0.004	1.87E-05
M-G3	7/11/14 8:00	520	1385	23.1	0.96	5.6	7055	19874	0.002	0.002	3.18E-05
M-G4	7/11/14 15:30	450	1835	30.6	1.27	5.3	9440	26593	0.003	0.004	4.26E-05
M-G5	7/11/14 23:37	487	2322	38.7	1.61	5.3	12021	33863	0.003	0.004	5.42E-05
M-G6	7/12/14 8:00	503	2825	47.1	1.96	5.3	14687	41373	0.005	0.006	6.62E-05
M-G7	7/12/14 16:30	510	3335	55.6	2.32	5.3	17390	48987	0.009	0.011	7.82E-05
M-G8	7/12/14 23:40	430	3765	62.7	2.61	5.3	19669	55407	0.008	0.010	8.84E-05
M-G9	7/13/14 7:30	470	4235	70.6	2.94	5.3	22160	62424	0.011	0.014	9.96E-05
M-G10	7/13/14 15:50	500	4735	78.9	3.29	5.3	24810	69888	0.012	0.015	1.11E-04
M-G11	7/13/14 23:20	450	5185	86.4	3.60	5.3	27195	76607	0.014	0.017	1.22E-04
M-G12	7/14/14 8:00	520	5705	95.1	3.96	5.3	29951	84370	0.023	0.029	1.34E-04
M-G13	7/14/14 15:45	465	6170	102.8	4.28	5.3	32416	91312	0.037	0.046	1.45E-04
M-G14	7/14/14 23:47	482	6652	110.9	4.62	5.3	34970	98508	0.038	0.047	1.56E-04
M-G15	7/15/14 8:05	498	7150	119.2	4.97	5.3	37610	105943	0.047	0.059	1.67E-04
M-G16	7/15/14 15:20	435	7585	126.4	5.27	5.3	39915	112438	0.046	0.057	1.77E-04
M-G17	7/15/14 23:00	460	8045	134.1	5.59	5.22	42317	119202	0.046	0.057	1.87E-04
M-G18	7/16/14 8:00	540	8585	143.1	5.96	5.22	45135	127142	0.054	0.067	1.99E-04
M-G19	7/16/14 15:34	454	9039	150.6	6.28	5.22	47505	133818	0.063	0.079	2.09E-04
M-G20	7/16/14 23:00	446	9485	158.1	6.59	5.22	49833	140376	0.071	0.088	2.18E-04
M-G21	7/17/14 8:15	555	10040	167.3	6.97	5.07	52647	148302	0.077	0.096	2.30E-04
M-G22	7/17/14 15:00	405	10445	174.1	7.25	5.07	54701	154086	0.086	0.107	2.38E-04
M-G23	7/17/14 23:48	528	10973	182.9	7.62	5.07	57378	161627	0.097	0.121	2.49E-04
M-G24	7/18/14 8:15	507	11480	191.3	7.97	5.07	59948	168868	0.106	0.132	2.59E-04
M-G25	7/18/14 15:30	435	11915	198.6	8.27	5.07	62153	175080	0.105	0.131	2.68E-04
M-G26	7/18/14 23:50	500	12415	206.9	8.62	5.07	64688	182221	0.121	0.151	2.77E-04
M-G27	7/19/14 7:15	445	12860	214.3	8.93	5.07	66945	188576	0.129	0.161	2.86E-04
M-G30	7/20/14 8:10	1495	14355	239.3	9.97	5.07	74524	209927	0.155	0.193	3.13E-04
M-G32	7/20/14 23:57	947	15302	255.0	10.63	5.07	79326	223452	0.190	0.237	3.30E-04
M-G34	7/21/14 16:00	963	16265	271.1	11.30	5.07	84208	237205	0.225	0.280	3.46E-04



Kunia I - Carbon D, F, G (Run #8)
TCP Concentration (ppb)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50000
100000
150000
200000
250000
300000
350000
400000
Bedvolumes
Carbon D
Carbon F
Carbon G

7.2.8 GAC Run #9

Run #9		
Waipahu III		
Carbon A/B, D, F		
A/B	5.10	mL/min
D	6.63	mL/min
F	5.10	mL/min
Bed Volume	0.355	mL
TCP Influent	0.634	ppb

Sample ID	TCP Conc. (ppb)
K-Infl1	0.637
K-Infl2	0.638
K-Infl3	0.626
Infl. Avg	0.634

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0063	0.0317	0.0634
A/B	1.299E-04	2.013E-04	2.490E-04
D	2.012E-04	2.637E-04	3.158E-04
F	1.554E-04	2.319E-04	2.707E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0063	0.0317	0.0634
A/B	102778	160689	201499
D	159063	209765	252562
F	122887	184938	218307

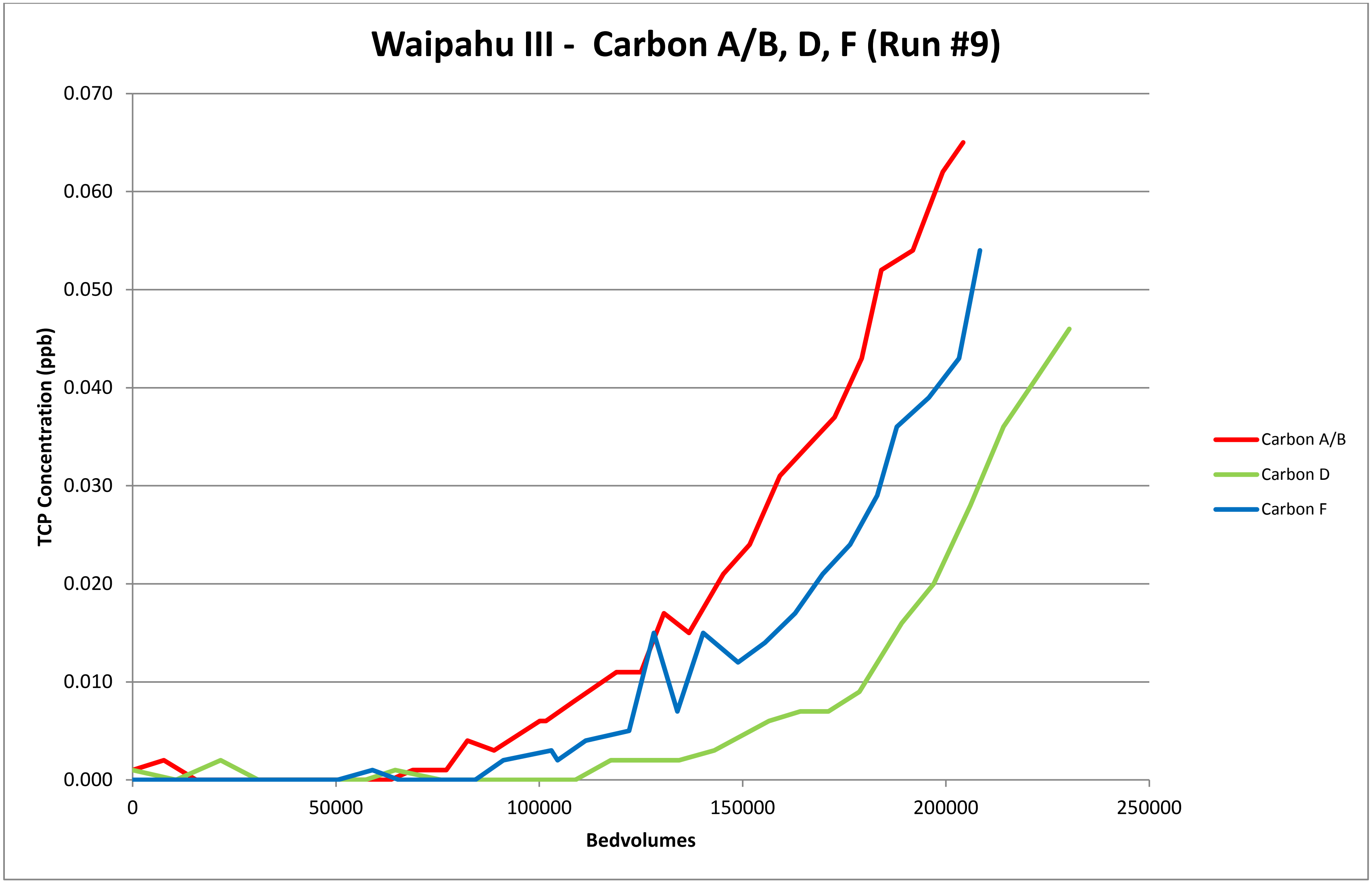
Carbon	A/B

Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-A/B1	7/28/14 14:00	0	0	0.0	0.00	5.13	0	0	0.001	0.002	0
W-A/B2	7/28/14 22:50	530	530	8.8	0.37	5.13	2719	7659	0.002	0.003	9.68E-06
W-A/B3	7/29/14 8:00	550	1080	18.0	0.75	5.13	5540	15607	0.000	0.000	1.97E-05
W-A/B4	7/29/14 15:42	462	1542	25.7	1.07	5.13	7910	22283	0.000	0.000	2.82E-05
W-A/B5	7/30/14 0:00	498	2040	34.0	1.42	5.08	10440	29409	0.000	0.000	3.72E-05
W-A/B6	7/30/14 7:40	460	2500	41.7	1.74	5.07	12772	35979	0.000	0.000	4.56E-05
W-A/B7	7/30/14 15:25	465	2965	49.4	2.06	5.07	15130	42620	0.000	0.000	5.40E-05
W-A/B8	7/30/14 22:00	395	3360	56.0	2.33	5.01	17109	48194	0.000	0.000	6.10E-05
W-A/B9	7/31/14 8:09	609	3969	66.1	2.76	5.01	20160	56789	0.000	0.000	7.19E-05
W-A/B10	7/31/14 15:56	467	4436	73.9	3.08	5.01	22500	63380	0.000	0.000	8.03E-05
W-A/B11	7/31/14 22:25	389	4825	80.4	3.35	5.03	24456	68891	0.001	0.002	8.73E-05
W-A/B12	8/1/14 8:05	580	5405	90.1	3.75	5.03	27374	77109	0.001	0.002	9.77E-05
W-A/B13	8/1/14 14:13	368	5773	96.2	4.01	5.03	29225	82324	0.004	0.006	1.04E-04
W-A/B14	8/1/14 22:00	467	6240	104.0	4.33	5.00	31560	88901	0.003	0.005	1.13E-04
W-A/B15	8/2/14 11:14	794	7034	117.2	4.88	5.00	35530	100084	0.006	0.009	1.27E-04
W-A/B16	8/2/14 13:00	106	7140	119.0	4.96	5.19	36080	101634	0.006	0.009	1.29E-04
W-A/B17	8/2/14 20:45	465	7605	126.8	5.28	5.19	38493	108432	0.008	0.013	1.37E-04
W-A/B18	8/3/14 8:45	720	8325	138.8	5.78	5.19	42230	118958	0.011	0.017	1.50E-04
W-A/B19	8/3/14 15:38	413	8738	145.6	6.07	5.19	44374	124996	0.011	0.017	1.58E-04
W-A/B20	8/3/14 22:19	401	9139	152.3	6.35	5.00	46379	130644	0.017	0.027	1.65E-04
W-A/B21	8/4/14 5:38	439	9578	159.6	6.65	5.00	48574	136827	0.015	0.024	1.72E-04
W-A/B22	8/4/14 15:37	599	10177	169.6	7.07	5.00	51569	145264	0.021	0.033	1.83E-04
W-A/B23	8/4/14 23:14	457	10634	177.2	7.38	5.00	53854	151700	0.024	0.038	1.90E-04
W-A/B24	8/5/14 8:05	531	11165	186.1	7.75	4.98	56498	159149	0.031	0.049	1.99E-04
W-A/B25	8/5/14 16:07	482	11647	194.1	8.09	4.98	58898	165911	0.034	0.054	2.08E-04
W-A/B26	8/6/14 0:05	478	12125	202.1	8.42	4.98	61279	172616	0.037	0.058	2.16E-04
W-A/B27	8/6/14 8:01	476	12601	210.0	8.75	4.98	63649	179294	0.043	0.068	2.23E-04
W-A/B28	8/6/14 13:49	348	12949	215.8	8.99	4.90	65354	184097	0.052	0.082	2.29E-04
W-A/B29	8/6/14 23:10	561	13510	225.2	9.38	4.90	68103	191841	0.054	0.085	2.38E-04
W-A/B30	8/7/14 8:03	533	14043	234.0	9.75	4.90	70715	199197	0.062	0.098	2.46E-04
W-A/B31	8/7/14 14:09	366	14409	240.1	10.01	4.90	72508	204249	0.065	0.103	2.52E-04

Carbon	D										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-D1	7/28/14 14:00	0	0	0.0	0.00	7.12	0	0	0.001	0.002	0
W-D2	7/28/14 22:50	530	530	8.8	0.37	7.12	3774	10630	0.000	0.000	1.35E-05
W-D3	7/29/14 8:00	550	1080	18.0	0.75	7.12	7690	21661	0.002	0.003	2.74E-05
W-D4	7/29/14 15:42	462	1542	25.7	1.07	7.12	10979	30927	0.000	0.000	3.92E-05
W-D5	7/30/14 0:00	498	2040	34.0	1.42	6.3	14116	39765	0.000	0.000	5.04E-05
W-D6	7/30/14 7:40	460	2500	41.7	1.74	6.71	17203	48459	0.000	0.000	6.14E-05
W-D7	7/30/14 15:25	465	2965	49.4	2.06	6.71	20323	57248	0.000	0.000	7.25E-05
W-D8	7/30/14 22:00	395	3360	56.0	2.33	6.58	22922	64570	0.001	0.002	8.18E-05
W-D9	7/31/14 8:09	609	3969	66.1	2.76	6.58	26930	75858	0.000	0.000	9.61E-05
W-D10	7/31/14 15:56	467	4436	73.9	3.08	6.58	30002	84514	0.000	0.000	1.07E-04
W-D11	7/31/14 22:25	389	4825	80.4	3.35	6.47	32519	91603	0.000	0.000	1.16E-04
W-D12	8/1/14 8:05	580	5405	90.1	3.75	6.47	36272	102174	0.000	0.000	1.29E-04
W-D13	8/1/14 14:13	368	5773	96.2	4.01	6.47	38653	108881	0.000	0.000	1.38E-04
W-D14	8/1/14 22:00	467	6240	104.0	4.33	6.62	41744	117590	0.002	0.003	1.49E-04
W-D15	8/2/14 11:14	794	7034	117.2	4.88	6.62	47001	132396	0.002	0.003	1.68E-04
W-D16	8/2/14 13:00	106	7140	119.0	4.96	6.62	47702	134373	0.002	0.003	1.70E-04
W-D17	8/2/14 20:45	465	7605	126.8	5.28	6.62	50781	143044	0.003	0.005	1.81E-04
W-D18	8/3/14 8:45	720	8325	138.8	5.78	6.62	55547	156470	0.006	0.009	1.98E-04
W-D19	8/3/14 15:38	413	8738	145.6	6.07	6.62	58281	164172	0.007	0.011	2.08E-04
W-D20	8/3/14 22:19	401	9139	152.3	6.35	6.15	60747	171119	0.007	0.011	2.16E-04
W-D21	8/4/14 5:38	439	9578	159.6	6.65	6.15	63447	178724	0.009	0.014	2.26E-04
W-D22	8/4/14 15:37	599	10177	169.6	7.07	6.15	67131	189101	0.016	0.025	2.39E-04
W-D23	8/4/14 23:14	457	10634	177.2	7.38	6.15	69941	197018	0.020	0.032	2.48E-04
W-D24	8/5/14 8:05	531	11165	186.1	7.75	6.01	73133	206008	0.028	0.044	2.59E-04
W-D25	8/5/14 16:07	482	11647	194.1	8.09	6.01	76030	214168	0.036	0.057	2.69E-04
W-D26	8/6/14 0:05	478	12125	202.1	8.42	6.01	78902	222260	0.041	0.065	2.79E-04
W-D27	8/6/14 8:01	476	12601	210.0	8.75	6.01	81763	230319	0.046	0.073	2.88E-04

Carbon	F										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-F1	7/28/14 14:00	0	0	0.0	0.00	5.82	0	0	0.000	0.000	0
W-F2	7/28/14 22:50	530	530	8.8	0.37	5.82	3085	8689	0.000	0.000	1.10E-05
W-F3	7/29/14 8:00	550	1080	18.0	0.75	5.82	6286	17706	0.000	0.000	2.24E-05
W-F4	7/29/14 15:42	462	1542	25.7	1.07	5.82	8974	25280	0.000	0.000	3.20E-05
W-F5	7/30/14 0:00	498	2040	34.0	1.42	4.6	11265	31733	0.000	0.000	4.02E-05
W-F6	7/30/14 7:40	460	2500	41.7	1.74	5.04	13584	38264	0.000	0.000	4.85E-05
W-F7	7/30/14 15:25	465	2965	49.4	2.06	5.04	15927	44865	0.000	0.000	5.69E-05
W-F8	7/30/14 22:00	395	3360	56.0	2.33	4.98	17894	50407	0.000	0.000	6.39E-05
W-F9	7/31/14 8:09	609	3969	66.1	2.76	4.98	20927	58950	0.001	0.002	7.47E-05
W-F10	7/31/14 15:56	467	4436	73.9	3.08	4.98	23253	65501	0.000	0.000	8.30E-05
W-F11	7/31/14 22:25	389	4825	80.4	3.35	4.98	25190	70958	0.000	0.000	8.99E-05
W-F12	8/1/14 8:05	580	5405	90.1	3.75	4.98	28078	79094	0.000	0.000	1.00E-04
W-F13	8/1/14 14:13	368	5773	96.2	4.01	4.98	29911	84257	0.000	0.000	1.07E-04
W-F14	8/1/14 22:00	467	6240	104.0	4.33	5.26	32367	91176	0.002	0.003	1.16E-04
W-F15	8/2/14 11:14	794	7034	117.2	4.88	5.26	36544	102941	0.003	0.005	1.30E-04
W-F16	8/2/14 13:00	106	7140	119.0	4.96	5.26	37101	104511	0.002	0.003	1.32E-04
W-F17	8/2/14 20:45	465	7605	126.8	5.28	5.26	39547	111401	0.004	0.006	1.41E-04
W-F18	8/3/14 8:45	720	8325	138.8	5.78	5.26	43335	122069	0.005	0.008	1.54E-04
W-F19	8/3/14 15:38	413	8738	145.6	6.07	5.26	45507	128189	0.015	0.024	1.62E-04
W-F20	8/3/14 22:19	401	9139	152.3	6.35	5.11	47556	133961	0.007	0.011	1.69E-04
W-F21	8/4/14 5:38	439	9578	159.6	6.65	5.11	49799	140280	0.015	0.024	1.77E-04
W-F22	8/4/14 15:37	599	10177	169.6	7.07	5.11	52860	148902	0.012	0.019	1.88E-04
W-F23	8/4/14 23:14	457	10634	177.2	7.38	5.11	55196	155480	0.014	0.022	1.96E-04
W-F24	8/5/14 8:05	531	11165	186.1	7.75	4.98	57840	162929	0.017	0.027	2.05E-04
W-F25	8/5/14 16:07	482	11647	194.1	8.09	4.98	60240	169691	0.021	0.033	2.13E-04
W-F26	8/6/14 0:05	478	12125	202.1	8.42	4.98	62621	176396	0.024	0.038	2.22E-04
W-F27	8/6/14 8:01	476	12601	210.0	8.75	4.98	64991	183074	0.029	0.046	2.30E-04

W-F28	8/6/14 13:49	348	12949	215.8	8.99	4.96	66717	187936	0.036	0.057	2.35E-04
W-F29	8/6/14 23:10	561	13510	225.2	9.38	4.96	69500	195774	0.039	0.062	2.45E-04
W-F30	8/7/14 8:03	533	14043	234.0	9.75	4.96	72144	203221	0.043	0.068	2.54E-04
W-F31	8/7/14 14:09	366	14409	240.1	10.01	4.96	73959	208335	0.054	0.085	2.60E-04


Waipahu III - Carbon A/B, D, F (Run #9)
TCP Concentration (ppb)
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
50000
100000
150000
200000
250000
Bedvolumes
Carbon A/B
Carbon D
Carbon F

7.2.9 GAC Run #10

Run #10		
Waipahu III		
Carbon C, E, G		
C	11.32	mL/min
E	6.63	mL/min
G	5.10	mL/min
Bed Volume	0.355	mL
TCP Influent	0.634	ppb

Sample ID	TCP Conc. (ppb)
K-Infl1	0.637
K-Infl2	0.638
K-Infl3	0.626
Infl. Avg	0.634

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0063	0.0317	0.0634
C	4.438E-05	8.401E-05	1.117E-04
E	2.078E-04	2.885E-04	3.410E-04
G	1.523E-04	2.316E-04	2.818E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0063	0.0317	0.0634
C	35212	67711	91732
E	164259	230054	275083
G	120380	185023	227708

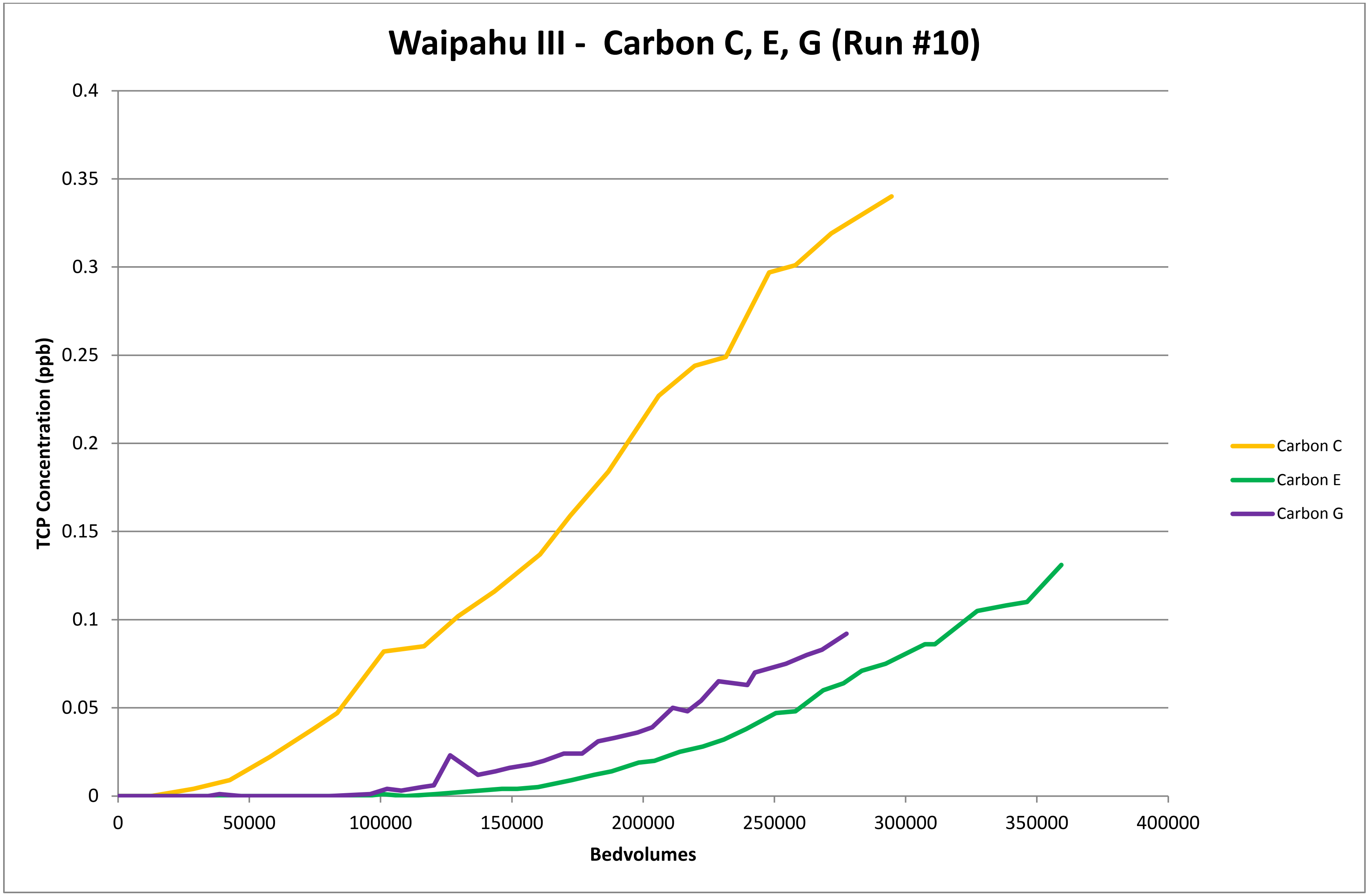
Carbon	C										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-C1	8/12/14 16:40	0	0	0.0	0.00	11.18	0	0	0	0.000	0
W-C2	8/12/14 23:17	397	397	6.6	0.28	11.18	4438	12503	0	0.000	1.58E-05
W-C3	8/13/14 8:05	528	925	15.4	0.64	10.92	10204	28744	0.004	0.006	3.63E-05
W-C4	8/13/14 15:28	443	1368	22.8	0.95	11.09	15117	42583	0.009	0.014	5.36E-05
W-C5	8/13/14 23:31	483	1851	30.8	1.29	11.09	20474	57672	0.022	0.035	7.20E-05
W-C6	8/14/14 8:22	531	2382	39.7	1.65	11.09	26362	74260	0.038	0.060	9.18E-05
W-C7	8/14/14 13:30	308	2690	44.8	1.87	10.58	29621	83439	0.047	0.074	1.03E-04
W-C8	8/14/14 23:25	595	3285	54.8	2.28	10.58	35916	101172	0.082	0.129	1.22E-04
W-C9	8/15/14 8:02	517	3802	63.4	2.64	10.58	41386	116580	0.085	0.134	1.39E-04
W-C10	8/15/14 15:15	433	4235	70.6	2.94	10.58	45967	129485	0.102	0.161	1.53E-04
W-C11	8/15/14 23:00	465	4700	78.3	3.26	10.58	50887	143343	0.116	0.183	1.67E-04
W-C12	8/16/14 8:42	582	5282	88.0	3.67	10.58	57044	160688	0.137	0.216	1.84E-04
W-C13	8/16/14 15:01	379	5661	94.4	3.93	10.80	61138	172218	0.159	0.251	1.95E-04
W-C14	8/16/14 23:00	479	6140	102.3	4.26	10.80	66311	186791	0.184	0.290	2.08E-04
W-C15	8/17/14 9:30	630	6770	112.8	4.70	10.80	73115	205957	0.227	0.358	2.24E-04
W-C16	8/17/14 17:00	450	7220	120.3	5.01	10.80	77975	219647	0.244	0.385	2.35E-04
W-C17	8/17/14 23:28	388	7608	126.8	5.28	10.80	82165	231451	0.249	0.393	2.44E-04
W-C18	8/18/14 8:33	545	8153	135.9	5.66	10.80	88051	248031	0.297	0.469	2.55E-04
W-C19	8/18/14 13:49	316	8469	141.1	5.88	11.20	91590	258001	0.301	0.475	2.62E-04
W-C20	8/18/14 21:00	431	8900	148.3	6.18	11.20	96418	271599	0.319	0.503	2.70E-04
W-C21	8/19/14 9:09	729	9629	160.5	6.69	11.20	104582	294598	0.340	0.537	2.84E-04

Carbon	E										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-E1	8/12/14 16:40	0	0	0.0	0.00	6.62	0	0	0.000	0.000	0
W-E2	8/12/14 23:17	397	397	6.6	0.28	6.72	2668	7515	0.000	0.000	9.52E-06
W-E3	8/13/14 8:05	528	925	15.4	0.64	6.47	6084	17138	0.000	0.000	2.17E-05
W-E4	8/13/14 15:28	443	1368	22.8	0.95	6.64	9026	25424	0.000	0.000	3.22E-05
W-E5	8/13/14 23:31	483	1851	30.8	1.29	6.53	12180	34308	0.000	0.000	4.35E-05
W-E6	8/14/14 8:22	531	2382	39.7	1.65	6.53	15647	44076	0.000	0.000	5.59E-05
W-E7	8/14/14 13:30	308	2690	44.8	1.87	6.08	17520	49351	0.000	0.000	6.25E-05
W-E8	8/14/14 23:25	595	3285	54.8	2.28	6.08	21137	59541	0.000	0.000	7.55E-05
W-E9	8/15/14 8:02	517	3802	63.4	2.64	6.08	24281	68396	0.000	0.000	8.67E-05
W-E10	8/15/14 15:15	433	4235	70.6	2.94	6.08	26913	75812	0.000	0.000	9.61E-05
W-E11	8/15/14 23:00	465	4700	78.3	3.26	6.08	29740	83776	0.000	0.000	1.06E-04
W-E12	8/16/14 8:42	582	5282	88.0	3.67	6.08	33279	93743	0.000	0.000	1.19E-04
W-E13	8/16/14 15:01	379	5661	94.4	3.93	6.50	35742	100683	0.001	0.002	1.28E-04
W-E14	8/16/14 23:00	479	6140	102.3	4.26	6.50	38856	109453	0.000	0.000	1.39E-04
W-E15	8/17/14 9:30	630	6770	112.8	4.70	6.50	42951	120989	0.001	0.002	1.53E-04
W-E16	8/17/14 17:00	450	7220	120.3	5.01	6.50	45876	129228	0.002	0.003	1.64E-04
W-E18	8/18/14 8:33	933	8153	135.9	5.66	6.48	51922	146259	0.004	0.006	1.85E-04
W-E19	8/18/14 13:49	316	8469	141.1	5.88	6.50	53976	152044	0.004	0.006	1.92E-04
W-E20	8/18/14 21:00	431	8900	148.3	6.18	6.50	56777	159936	0.005	0.008	2.02E-04
W-E21	8/19/14 9:09	729	9629	160.5	6.69	6.30	61370	172873	0.009	0.014	2.19E-04
W-E22	8/19/14 17:03	474	10103	168.4	7.02	6.30	64356	181285	0.012	0.019	2.29E-04
W-E23	8/19/14 23:23	380	10483	174.7	7.28	6.30	66750	188029	0.014	0.022	2.37E-04
W-E24	8/20/14 9:01	578	11061	184.4	7.68	6.30	70392	198286	0.019	0.030	2.50E-04
W-E25	8/20/14 14:42	341	11402	190.0	7.92	6.30	72540	204338	0.020	0.032	2.57E-04
W-E26	8/20/14 23:44	542	11944	199.1	8.29	6.30	75954	213956	0.025	0.039	2.69E-04
W-E27	8/21/14 7:55	491	12435	207.2	8.64	6.30	79048	222670	0.028	0.044	2.80E-04
W-E28	8/21/14 15:05	430	12865	214.4	8.93	6.62	81894	230688	0.032	0.050	2.89E-04
W-E29	8/21/14 22:40	455	13320	222.0	9.25	6.62	84906	239173	0.038	0.060	2.99E-04
W-E30	8/22/14 8:52	612	13932	232.2	9.67	6.62	88958	250586	0.047	0.074	3.13E-04
W-E31	8/22/14 15:30	398	14330	238.8	9.95	6.62	91593	258008	0.048	0.076	3.21E-04
W-E32	8/23/14 0:51	561	14891	248.2	10.34	6.69	95346	268580	0.060	0.095	3.34E-04

W-E33	8/23/14 7:41	410	15301	255.0	10.63	6.69	98089	276306	0.064	0.101	3.42E-04
W-E34	8/23/14 13:52	371	15672	261.2	10.88	6.69	100571	283298	0.071	0.112	3.50E-04
W-E35	8/23/14 21:50	478	16150	269.2	11.22	6.69	103768	292306	0.075	0.118	3.60E-04
W-E36	8/24/14 11:07	797	16947	282.4	11.77	6.69	109100	307325	0.086	0.136	3.77E-04
W-E37	8/24/14 14:27	200	17147	285.8	11.91	6.69	110438	311094	0.086	0.136	3.81E-04
W-E38	8/25/14 4:45	858	18005	300.1	12.50	6.69	116178	327263	0.105	0.166	3.98E-04
W-E40	8/25/14 14:24	579	18584	309.7	12.91	6.71	120064	338207	0.108	0.170	4.10E-04
W-E41	8/25/14 21:30	426	19010	316.8	13.20	6.71	122922	346259	0.110	0.174	4.18E-04
W-E42	8/26/14 9:00	690	19700	328.3	13.68	6.71	127552	359301	0.131	0.207	4.31E-04

Carbon	G										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W-G1	8/12/14 16:40	0	0	0.0	0.00	7.6	0	0	0.000	0.000	0
W-G2	8/12/14 23:17	397	397	6.6	0.28	5.18	2056	5793	0.000	0.000	7.34E-06
W-G3	8/13/14 8:05	528	925	15.4	0.64	5.01	4702	13244	0.000	0.000	1.68E-05
W-G4	8/13/14 15:28	443	1368	22.8	0.95	5.16	6988	19683	0.000	0.000	2.49E-05
W-G5	8/13/14 23:31	483	1851	30.8	1.29	5.10	9451	26622	0.000	0.000	3.37E-05
W-G6	8/14/14 8:22	531	2382	39.7	1.65	5.10	12159	34251	0.000	0.000	4.34E-05
W-G7	8/14/14 13:30	308	2690	44.8	1.87	5.00	13699	38589	0.001	0.002	4.89E-05
W-G8	8/14/14 23:25	595	3285	54.8	2.28	5.00	16674	46969	0.000	0.000	5.95E-05
W-G9	8/15/14 8:02	517	3802	63.4	2.64	5.00	19259	54251	0.000	0.000	6.87E-05
W-G10	8/15/14 15:15	433	4235	70.6	2.94	5.00	21424	60349	0.000	0.000	7.65E-05
W-G11	8/15/14 23:00	465	4700	78.3	3.26	5.00	23749	66899	0.000	0.000	8.48E-05
W-G12	8/16/14 8:42	582	5282	88.0	3.67	5.00	26659	75096	0.000	0.000	9.52E-05
W-G13	8/16/14 15:01	379	5661	94.4	3.93	5.01	28558	80445	0.000	0.000	1.02E-04
W-G15	8/17/14 9:30	1109	6770	112.8	4.70	5.01	34114	96095	0.001	0.002	1.22E-04
W-G16	8/17/14 17:00	450	7220	120.3	5.01	5.01	36368	102446	0.004	0.006	1.30E-04
W-G17	8/17/14 23:28	388	7608	126.8	5.28	5.01	38312	107922	0.003	0.005	1.37E-04
W-G18	8/18/14 8:33	545	8153	135.9	5.66	5.06	41070	115690	0.005	0.008	1.46E-04
W-G19	8/18/14 13:49	316	8469	141.1	5.88	5.13	42691	120257	0.006	0.009	1.52E-04
W-G20	8/18/14 21:00	431	8900	148.3	6.18	5.13	44902	126485	0.023	0.036	1.60E-04
W-G21	8/19/14 9:09	729	9629	160.5	6.69	5.13	48642	137019	0.012	0.019	1.73E-04
W-G22	8/19/14 17:03	474	10103	168.4	7.02	5.03	51026	143735	0.014	0.022	1.81E-04
W-G23	8/19/14 23:23	380	10483	174.7	7.28	5.03	52937	149120	0.016	0.025	1.88E-04
W-G24	8/20/14 9:01	578	11061	184.4	7.68	5.03	55845	157309	0.018	0.028	1.98E-04
W-G25	8/20/14 14:42	341	11402	190.0	7.92	5.03	57560	162141	0.020	0.032	2.04E-04
W-G26	8/20/14 23:44	542	11944	199.1	8.29	5.03	60286	169821	0.024	0.038	2.13E-04
W-G27	8/21/14 7:55	491	12435	207.2	8.64	5.03	62756	176778	0.024	0.038	2.22E-04
W-G28	8/21/14 15:05	430	12865	214.4	8.93	5.00	64906	182834	0.031	0.049	2.29E-04
W-G29	8/21/14 22:40	455	13320	222.0	9.25	5.00	67181	189242	0.033	0.052	2.37E-04
W-G30	8/22/14 8:52	612	13932	232.2	9.67	5.00	70241	197862	0.036	0.057	2.47E-04

W-G31	8/22/14 15:30	398	14330	238.8	9.95	5.00	72231	203468	0.039	0.062	2.54E-04
W-G32	8/23/14 0:51	561	14891	248.2	10.34	4.92	74991	211243	0.050	0.079	2.63E-04
W-G33	8/23/14 7:41	410	15301	255.0	10.63	4.92	77008	216925	0.048	0.076	2.69E-04
W-G34	8/23/14 13:52	371	15672	261.2	10.88	4.92	78834	222067	0.054	0.085	2.75E-04
W-G35	8/23/14 21:50	478	16150	269.2	11.22	4.92	81185	228691	0.065	0.103	2.83E-04
W-G36	8/24/14 11:07	797	16947	282.4	11.77	4.92	85107	239737	0.063	0.099	2.95E-04
W-G37	8/24/14 14:27	200	17147	285.8	11.91	4.92	86091	242509	0.070	0.110	2.99E-04
W-G38	8/25/14 4:45	858	18005	300.1	12.50	4.92	90312	254400	0.075	0.118	3.12E-04
W-G40	8/25/14 14:24	579	18584	309.7	12.91	4.84	93114	262294	0.080	0.126	3.21E-04
W-G41	8/25/14 21:30	426	19010	316.8	13.20	4.84	95176	268102	0.083	0.131	3.27E-04
W-G42	8/26/14 9:00	690	19700	328.3	13.68	4.84	98516	277509	0.092	0.145	3.37E-04



Waipahu III - Carbon C, E, G (Run #10)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
TCP Concentration (ppb)
0
50000
100000
150000
200000
250000
300000
350000
400000
Bedvolumes
Carbon C
Carbon E
Carbon G

7.2.10 GAC Run #11

Run #11		
Waipahu III		
Carbon A/B		
100 x 120	3.42	mL/min
120 x 140	4.07	mL/min
140 x 170	4.82	mL/min
170 x 200	5.74	mL/min
Bed Volume	0.355	mL
TCP Influent	0.506	ppb

Sample ID	TCP Conc. (ppb)
K-Infl1	0.550
K-Infl2	0.545
K-Infl3	0.492
K-Infl4	0.500
K-Infl5	0.452
K-Infl6	0.495
Infl. Avg	0.506

	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0051	0.0253	0.0506
100 x 120	3.478E-04	4.643E-04	5.345E-04
120 x 140	2.790E-04	3.569E-04	4.062E-04
140 x 170	2.635E-04	3.419E-04	3.823E-04
170 x 200	1.944E-04	2.373E-04	2.721E-04

	Bed - Volumes		
	1% Breakthru (ppb)	5% Breakthru (ppb)	10% Breakthru (ppb)
Limit Conc. (ppb)	0.0051	0.0253	0.0506
100 x 120	344371	462863	538015
120 x 140	276376	355973	409157
140 x 170	260776	340779	384473
170 x 200	192564	236700	274239

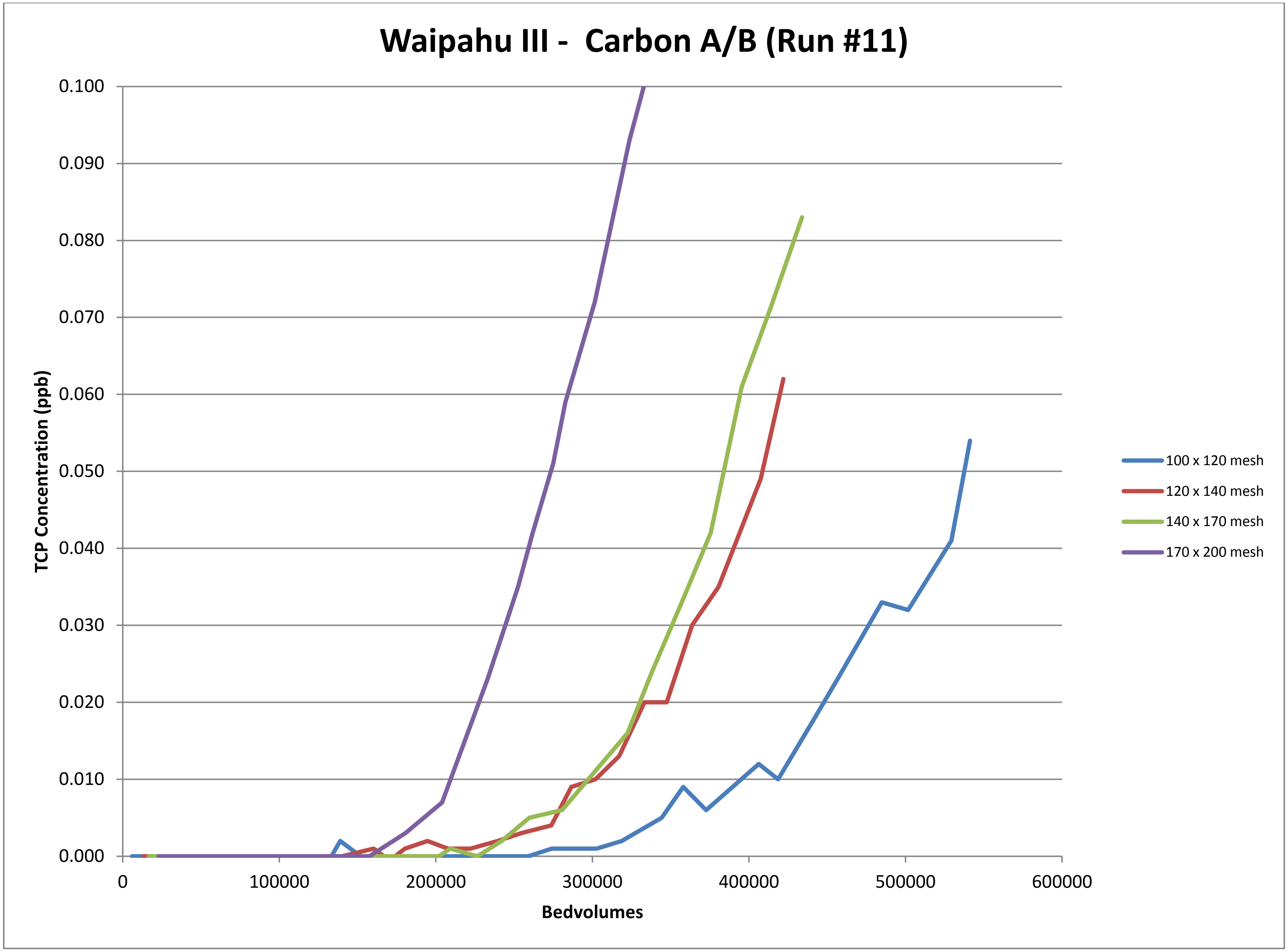
Carbon A/B	100 x 120 mesh										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W100x120-1	10/30/14 14:24	1167	1167	19.5	0.81	1.82	2124	5983	0.000	0.000	6.05E-06
W100x120-2	10/31/14 11:41	1277	2444	40.7	1.70	3.17	6172	17386	0.000	0.000	1.76E-05
W100x120-3	11/1/14 12:48	1507	3951	65.9	2.74	3.69	11733	33050	0.000	0.000	3.34E-05

W100x120-4	11/2/14 9:32	1244	5195	86.6	3.61	3.62	16236	45736	0.000	0.000	4.63E-05
W100x120-5	11/3/14 8:00	1348	6543	109.1	4.54	1.49	18245	51393	0.000	0.000	5.20E-05
W100x120-6	11/3/14 20:19	739	7282	121.4	5.06	1.49	19346	54495	0.000	0.000	5.51E-05
W100x120-7	11/4/14 13:11	1012	8294	138.2	5.76	3.26	22645	63788	0.000	0.000	6.45E-05
W100x120-9	11/5/14 10:46	1295	9589	159.8	6.66	3.02	26556	74805	0.000	0.000	7.57E-05
W100x120-10	11/6/14 9:54	1388	10977	183.0	7.62	3.32	31164	87786	0.000	0.000	8.88E-05
W100x120-11	11/7/14 9:06	1392	12369	206.2	8.59	3.76	36398	102529	0.000	0.000	1.04E-04
W100x120-12	11/8/14 14:06	1740	14109	235.2	9.80	3.76	42940	120959	0.000	0.000	1.22E-04
W100x120-13	11/8/14 23:23	557	14666	244.4	10.18	3.68	44990	126732	0.000	0.000	1.28E-04
W100x120-14	11/9/14 9:48	625	15291	254.9	10.62	3.68	47290	133211	0.000	0.000	1.35E-04
W100x120-15	11/9/14 18:58	550	15841	264.0	11.00	3.68	49314	138913	0.002	0.004	1.40E-04
W100x120-17	11/10/14 15:45	1247	17088	284.8	11.87	3.68	53903	151839	0.000	0.000	1.54E-04
W100x120-18	11/11/14 10:18	1113	18201	303.4	12.64	3.68	57999	163377	0.000	0.000	1.65E-04
W100x120-19	11/12/14 8:14	1316	19517	325.3	13.55	3.38	62447	175907	0.000	0.000	1.78E-04
W100x120-20	11/13/14 10:18	1564	21081	351.4	14.64	3.38	67733	190798	0.000	0.000	1.93E-04
W100x120-21	11/14/14 9:05	1367	22448	374.1	15.59	3.31	72258	203544	0.000	0.000	2.06E-04
W100x120-22	11/15/14 14:06	1741	24189	403.2	16.80	3.24	77899	219433	0.000	0.000	2.22E-04
W100x120-23	11/16/14 9:43	1177	25366	422.8	17.62	3.24	81712	230176	0.000	0.000	2.33E-04
W100x120-24	11/17/14 9:35	1432	26798	446.6	18.61	3.59	86853	244657	0.000	0.000	2.47E-04
W100x120-25	11/18/14 9:00	1405	28203	470.1	19.59	3.59	91897	258865	0.000	0.000	2.62E-04
W100x120-26	11/19/14 9:56	1496	29699	495.0	20.62	3.59	97268	273994	0.001	0.002	2.77E-04
W100x120-27	11/20/14 8:54	1378	31077	518.0	21.58	3.47	102049	287463	0.001	0.002	2.91E-04
W100x120-28	11/21/14 11:00	1566	32643	544.1	22.67	3.47	107483	302770	0.001	0.002	3.06E-04
W100x120-29	11/22/14 14:16	1636	34279	571.3	23.80	3.47	113160	318762	0.002	0.004	3.22E-04
W100x120-30	11/24/14 9:36	2600	36879	614.7	25.61	3.47	122182	344176	0.005	0.010	3.48E-04
W100x120-31	11/25/14 9:06	1410	38289	638.2	26.59	3.47	127075	357958	0.009	0.018	3.61E-04
W100x120-32	11/26/14 10:07	1501	39790	663.2	27.63	3.47	132284	372630	0.006	0.012	3.76E-04
W100x120-33	11/28/14 19:28	3441	43231	720.5	30.02	3.47	144224	406264	0.012	0.024	4.09E-04
W100x120-34	11/29/14 16:22	1254	44485	741.4	30.89	3.47	148575	418522	0.010	0.020	4.21E-04
W100x120-35	12/1/14 8:30	2408	46893	781.5	32.56	3.47	156931	442059	0.018	0.036	4.44E-04
W100x120-36	12/2/14 8:53	1463	48356	805.9	33.58	3.47	162008	456359	0.023	0.045	4.58E-04
W100x120-38	12/4/14 9:27	2914	51270	854.5	35.60	3.47	172119	484843	0.033	0.065	4.85E-04
W100x120-39	12/5/14 14:04	1717	52987	883.1	36.80	3.47	178077	501626	0.032	0.063	5.01E-04
W100x120-40	12/7/14 13:12	2828	55815	930.3	38.76	3.47	187890	529268	0.041	0.081	5.27E-04
W100x120-41	12/8/14 9:28	1216	57031	950.5	39.60	3.47	192110	541154	0.054	0.107	5.37E-04

Carbon A/B	120 x 140 mesh										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W120x140-1	10/30/14 14:24	1167	1167	19.5	0.81	3.98	4645	13084	0.000	0.000	1.32E-05
W120x140-2	10/31/14 11:41	1277	2444	40.7	1.70	3.9	9625	27113	0.000	0.000	2.74E-05
W120x140-3	11/1/14 12:48	1507	3951	65.9	2.74	3.87	15457	43541	0.000	0.000	4.40E-05
W120x140-4	11/2/14 9:32	1244	5195	86.6	3.61	3.9	20309	57207	0.000	0.000	5.79E-05
W120x140-6	11/3/14 20:19	2087	7282	121.4	5.06	4.06	28782	81076	0.000	0.000	8.20E-05
W120x140-8	11/4/14 14:24	1085	8367	139.5	5.81	4.03	33154	93393	0.000	0.000	9.45E-05
W120x140-10	11/6/14 9:54	2610	10977	183.0	7.62	4.13	43934	123757	0.000	0.000	1.25E-04
W120x140-11	11/7/14 9:06	1392	12369	206.2	8.59	4.14	49697	139990	0.000	0.000	1.42E-04
W120x140-12	11/8/14 14:06	1740	14109	235.2	9.80	4.14	56900	160282	0.001	0.002	1.62E-04
W120x140-13	11/8/14 23:23	557	14666	244.4	10.18	4.08	59173	166684	0.000	0.000	1.69E-04
W120x140-14	11/9/14 9:48	625	15291	254.9	10.62	4.08	61723	173867	0.000	0.000	1.76E-04
W120x140-15	11/9/14 18:58	550	15841	264.0	11.00	4.11	63983	180235	0.001	0.002	1.82E-04
W120x140-17	11/10/14 15:45	1247	17088	284.8	11.87	4.11	69108	194672	0.002	0.004	1.97E-04
W120x140-18	11/11/14 10:18	1113	18201	303.4	12.64	4.11	73683	207557	0.001	0.002	2.10E-04
W120x140-19	11/12/14 8:14	1316	19517	325.3	13.55	3.93	78855	222126	0.001	0.002	2.24E-04
W120x140-20	11/13/14 10:18	1564	21081	351.4	14.64	3.93	85001	239440	0.002	0.004	2.42E-04
W120x140-21	11/14/14 9:05	1367	22448	374.1	15.59	3.93	90374	254573	0.003	0.006	2.57E-04
W120x140-22	11/15/14 14:06	1741	24189	403.2	16.80	3.89	97146	273651	0.004	0.008	2.76E-04
W120x140-23	11/16/14 9:43	1177	25366	422.8	17.62	3.89	101725	286548	0.009	0.018	2.89E-04
W120x140-24	11/17/14 9:35	1432	26798	446.6	18.61	3.82	107195	301957	0.010	0.020	3.04E-04
W120x140-25	11/18/14 9:00	1405	28203	470.1	19.59	3.82	112562	317076	0.013	0.026	3.19E-04
W120x140-26	11/19/14 9:56	1496	29699	495.0	20.62	3.82	118277	333174	0.02	0.040	3.35E-04
W120x140-27	11/20/14 8:54	1378	31077	518.0	21.58	3.67	123334	347419	0.020	0.040	3.49E-04
W120x140-28	11/21/14 11:00	1566	32643	544.1	22.67	3.67	129081	363609	0.030	0.059	3.64E-04
W120x140-29	11/22/14 14:16	1636	34279	571.3	23.80	3.67	135085	380522	0.035	0.069	3.80E-04
W120x140-30	11/24/14 9:36	2600	36879	614.7	25.61	3.67	144627	407401	0.049	0.097	4.05E-04
W120x140-31	11/25/14 9:06	1410	38289	638.2	26.59	3.67	149802	421977	0.062	0.123	4.18E-04

Carbon A/B	140 x 170 mesh										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W140x170-1	10/30/14 14:24	1167	1167	19.5	0.81	5.06	5905	16634	0.000	0.000	1.68E-05
W140x170-2	10/31/14 11:41	1277	2444	40.7	1.70	4.87	12124	34152	0.000	0.000	3.45E-05
W140x170-3	11/1/14 12:48	1507	3951	65.9	2.74	4.01	18167	51175	0.000	0.000	5.18E-05
W140x170-4	11/2/14 9:32	1244	5195	86.6	3.61	4.12	23292	65612	0.000	0.000	6.64E-05
W140x170-6	11/3/14 20:19	2087	7282	121.4	5.06	4.76	33226	93596	0.000	0.000	9.47E-05
W140x170-8	11/4/14 14:24	1085	8367	139.5	5.81	4.84	38478	108388	0.000	0.000	1.10E-04
W140x170-9	11/5/14 10:46	1222	9589	159.8	6.66	4.71	44234	124601	0.000	0.000	1.26E-04
W140x170-10	11/6/14 9:54	1388	10977	183.0	7.62	4.86	50979	143603	0.000	0.000	1.45E-04
W140x170-11	11/7/14 9:06	1392	12369	206.2	8.59	4.80	57661	162425	0.000	0.000	1.64E-04
W140x170-12	11/8/14 14:06	1740	14109	235.2	9.80	4.80	66013	185951	0.000	0.000	1.88E-04
W140x170-14	11/9/14 9:48	1182	15291	254.9	10.62	4.74	71615	201734	0.000	0.000	2.04E-04
W140x170-15	11/9/14 18:58	550	15841	264.0	11.00	4.91	74316	209341	0.001	0.002	2.12E-04
W140x170-17	11/10/14 15:45	1247	17088	284.8	11.87	4.91	80439	226588	0.000	0.000	2.29E-04
W140x170-18	11/11/14 10:18	1113	18201	303.4	12.64	4.91	85904	241982	0.002	0.004	2.45E-04
W140x170-19	11/12/14 8:14	1316	19517	325.3	13.55	4.75	92155	259590	0.005	0.010	2.62E-04
W140x170-20	11/13/14 10:18	1564	21081	351.4	14.64	4.75	99584	280517	0.006	0.012	2.83E-04
W140x170-22	11/15/14 14:06	3108	24189	403.2	16.80	4.78	114440	322366	0.016	0.032	3.24E-04
W140x170-23	11/16/14 9:43	1177	25366	422.8	17.62	4.74	120019	338081	0.024	0.047	3.39E-04
W140x170-24	11/17/14 9:35	1432	26798	446.6	18.61	4.69	126735	357000	0.033	0.065	3.57E-04
W140x170-25	11/18/14 9:00	1405	28203	470.1	19.59	4.69	133324	375561	0.042	0.083	3.74E-04
W140x170-26	11/19/14 9:56	1496	29699	495.0	20.62	4.69	140341	395325	0.061	0.121	3.92E-04
W140x170-27	11/20/14 8:54	1378	31077	518.0	21.58	4.64	146734	413337	0.071	0.140	4.08E-04
W140x170-28	11/21/14 11:00	1566	32643	544.1	22.67	4.64	154001	433805	0.083	0.164	4.25E-04

Carbon A/B	170 x 200 mesh										
Sample ID	Date and Time	Time between consecutive samples (min)	Total Time (min)	Total Time (hrs)	Total Time (days)	Flow Rate (mL/min)	Treated Vol. (mL)	Bed Volumes	Conc. (ppb)	C/C_O	mg TCP Mass Adsorbed per kg GAC Mass (mg/kg)
W170x200-1	10/30/14 14:24	1167	1167	19.5	0.81	6.96	8122	22880	0.000	0.000	2.31E-05
W170x200-2	10/31/14 11:41	1277	2444	40.7	1.70	6.21	16052	45218	0.000	0.000	4.57E-05
W170x200-3	11/1/14 12:48	1507	3951	65.9	2.74	5.59	24477	68948	0.000	0.000	6.97E-05
W170x200-4	11/2/14 9:32	1244	5195	86.6	3.61	5.66	31518	88782	0.000	0.000	8.98E-05
W170x200-5	11/3/14 8:00	1348	6543	109.1	4.54	5.65	39134	110236	0.000	0.000	1.11E-04
W170x200-6	11/3/14 20:19	739	7282	121.4	5.06	5.65	43309	121998	0.000	0.000	1.23E-04
W170x200-7	11/4/14 13:11	1012	8294	138.2	5.76	5.59	48966	137933	0.000	0.000	1.39E-04
W170x200-9	11/5/14 10:46	1295	9589	159.8	6.66	5.38	55933	157559	0.000	0.000	1.59E-04
W170x200-10	11/6/14 9:54	1388	10977	183.0	7.62	5.89	64109	180588	0.003	0.006	1.82E-04
W170x200-11	11/7/14 9:06	1392	12369	206.2	8.59	5.94	72377	203879	0.007	0.014	2.06E-04
W170x200-12	11/8/14 14:06	1740	14109	235.2	9.80	5.94	82713	232994	0.023	0.045	2.34E-04
W170x200-14	11/9/14 9:48	1182	15291	254.9	10.62	5.85	89627	252472	0.035	0.069	2.52E-04
W170x200-15	11/9/14 18:58	550	15841	264.0	11.00	5.97	92911	261721	0.042	0.083	2.61E-04
W170x200-16	11/10/14 8:00	782	16623	277.1	11.54	5.97	97580	274872	0.051	0.101	2.73E-04
W170x200-17	11/10/14 15:45	465	17088	284.8	11.87	5.97	100356	282692	0.059	0.117	2.80E-04
W170x200-18	11/11/14 10:18	1113	18201	303.4	12.64	5.97	107000	301409	0.072	0.142	2.96E-04
W170x200-19	11/12/14 8:14	1316	19517	325.3	13.55	5.97	114857	323540	0.093	0.184	3.14E-04
W170x200-20	11/13/14 10:18	1564	21081	351.4	14.64	5.97	124194	349842	0.113	0.223	3.35E-04



Waipahu III - Carbon A/B (Run #11)
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
TCP Concentration (ppb)
0
100000
200000
300000
400000
500000
600000
Bedvolumes
100 x 120 mesh
120 x 140 mesh
140 x 170 mesh
170 x 200 mesh