Photocopy and Use Authorization

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Idaho State University, I agree that the Library shall make it freely available for inspection. I further state that permission for extensive copying of my thesis for scholarly purposes may be granted by the Dean of the Graduate School, Dean of my academic division, or by the University Librarian. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature ___________________________________

Date ______________________________________

USING INLINE HYGROMETERS TO REDUCE UNCERTAINTY
IN HTO SAMPLING

by

Travis Bennett

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Health Physics

Idaho State University

Fall 2019

Committee Approval

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Travis Bennett find it satisfactory and recommend that it be accepted.

____

Richard Brey, Ph. D, C.H.P
Major Advisor

____

Thomas Gesell, Ph. D.
Committee Member

____

Ken Aho, Ph. D.
Graduate Faculty Representative

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ANL – Argonne National Laboratory

ATM- Atmosphere

BKG- Background

Bq- Becquerel = $2.7x10^{-11}$ Ci

CFR- Code of Federal Regulations

CI- Confidence Interval

Ci- Curie = $3.7x10^{10}$ Bq

CNSC- Canadian Nuclear Safety Commission

CPM- Counts per Minute

DPM- Disintegrations per Minute

EAL- Environmental Assessment Laboratory

EML- Environmental Monitoring Laboratory

EPA- Environmental Protection Agency

eV – Electron-volts = $1.6x10^{-19}$ Joules

FR- Federal Register

HPS- Health Physics Society

HT- Tritiated Gas

HTO-Tritiated Water

IAEA- International Atomic Energy Agency

ICRP- International Commission on Radiological Protection

IDEQ-Idaho Department of Environmental Quality

INL- Idaho National Laboratory

ISO - International Organization for the Standardization

ISU- Idaho State University

LSC- Liquid Scintillation Counter

MCL- Maximum Contaminant Level

mGy - milligray

MS- Molecular Sieve

MWe = Megawatt-Electric

NCRP- National Council on Radiation Protection and Measurements

NIST- National Institute of Standards and Technology

NRC- Nuclear Regulatory Commission

OBT- Organically Bound Tritium

PCC – Pearson Correlation Coefficient

PPM- Parts per Million

RH% - Relative Humidity

STD- Standard

T_B – Biological Half life

T_E – Effective Half Life

UNSCEAR- United Nations Scientific Committee on the Effects of Atomic Radiation

Giga	G	10^9
Mega	M	10^6
Kilo	k	10^3
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	µ	10^{-6}
Nano	n	10^{-9}
Angstrom	Å	10^{-10}
Pico	P	10^{-12}

^{2}H	Deuterium
^{3}H	Tritium
^{3}He	Helium
^{6}Li	Lithium
^{10}B	Boron
^{60}Co	Cobalt
^{137}Cs	Cesium

Abstract

Using Inline Hygrometers to Reduce Uncertainty in HTO Sampling

Thesis Abstract – Idaho State University (2019)

The Idaho Department of Environmental Quality samples atmospheric tritiated water on and near the Idaho National Laboratory using molecular sieve to adsorb water vapor from the atmosphere. The IDEQ reports atmospheric HTO concentrations including analytical uncertainties, calculated using these water concentrations. Results from 434 HTO samples were reviewed to identify and possibly quantify unrealized uncertainty. Experimental sampling using an inline hygrometer was conducted to establish MS collection efficiencies. Data from the sample groups and associated operating conditions were reviewed; no correlation between sampling variables and HTO concentrations was found. The study was unable to incorporate collection efficiencies into the IDEQ's historical sampling data due to insufficient data. The calculated collection efficiencies were implemented into the IDEQ's sampling data, the observed collection efficiency values ranged from 28 to 333%; these values are either not possible or reasonable and are assumed to be a product of measurement uncertainty and procedural errors.

Key Words: atmospheric tritium sampling; molecular sieve adsorption; uncertainty analysis in tritium sampling.

Chapter 1: Introduction

1.1 Thesis Statement

The methods and materials incorporated in the sampling of atmospheric tritiated water (HTO) vapor by the Idaho Department of Environmental Quality (IDEQ) Oversight Program of the Idaho National Laboratory (INL) may include unrealized error contributions leading to atmospheric HTO concentrations with incomplete assessments of uncertainty. The variables and their associated uncertainties in calculating atmospheric HTO concentrations were identified by the IDEQ in their standard operating procedure SOP-002 (Ritter 2014). The variables believed to contribute most to uncertainty include temperature, humidity, and uncharacterized molecular sieve (MS) collection and retention efficiencies. A review of sampling data provided by the IDEQ revealed that a small percentage of samples may have additional uncertainty associated with the sample volume. (i.e. MS collection efficiency and sample collection). For example, 9 out of the 434 samples pulled off more liquid from the MS than the MS was recorded to have adsorbed during the sampling process. Uncertainty in MS collection and retention efficiencies would impact how the total sample volume is recorded, potentially underestimating atmospheric HTO concentrations.

Proposed improvements to quantify uncertainty previously unaccounted for include adding an inline hygrometer to provide real-time data (temperature and humidity) of the air being sampled, from which the HTO concentrations would be derived. The data provided by the hygrometer would quantify the collection efficiency and the associated uncertainty of the MS. The collection efficiency would be applied to the sample volume measurements and included into final atmospheric HTO concentrations. As per IDEQ SOP-002 (Ritter 2014) a reported MS collection efficiency of 95% would increase final atmospheric HTO concentrations by 5%, or 0.06 ± 0.03 pCi ml^{-1} (based on average sampling conditions).

1.1.1 Thesis Hypothesis

Concerning Atmospheric HTO Concentrations;

1a

- Null Hypothesis 1a– The differences in atmospheric HTO concentrations and associated uncertainties calculated using the sample specific MS collection efficiencies, based upon the data retrieved by the hygrometer, does not reduce uncertainty.
- Alternate Hypothesis 1a – The differences in atmospheric HTO concentrations and associated uncertainties calculated using the MS collection efficiencies, based upon the data retrieved by the hygrometer, does reduce uncertainty.
- Decision Rule 1a– the null hypothesis will fail to be rejected if the magnitude of the value of uncertainty increases.

Concerning the Relationship between MS Collection Efficiency and Temperature;

- Null Hypothesis 2a – No relationship between MS collection efficiency and Temperature exists.
- Alternate Hypothesis 2a – A linear, exponential, or logarithmic relationship between MS collection efficiency and Temperature exists.
- Decision Rule 2a – the null hypothesis will fail to be rejected if the Coefficient of Determination, or R^2, between MS collection efficiency and Temperature is between 0 and 0.7 for linear, exponential, and logarithmic functions.

Concerning the Relationship between MS Collection Efficiency and Humidity;

- Null Hypothesis 2b – No relationship between MS collection efficiency and Humidity exists.
- Alternate Hypothesis 2b – A linear, exponential, or logarithmic relationship between MS collection efficiency and Humidity exists.
- Decision Rule 2b – the null hypothesis will fail to be rejected if the Coefficient of Determination, or R^2, between MS collection efficiency and Humidity is between 0 and 0.7 for linear, exponential, and logarithmic functions.

1.2 Standards and Regulations

Tritium (^3H) is both a naturally occurring and artificially produced radionuclide. Anthropogenic HTO generation may result in much higher levels in locations near the generation source than what is found naturally. Government bodies, such as the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC), impose regulations to protect the public and environment. The imposed regulations create strict compliance standards for operating ^3H generating facilities. For example, "The Safe Drinking Water Act" will regulate the Maximum Contaminant Level (MCL) of radioactivity from both photon and beta particle emitter. This standard limits doses from HTO to 4 mrem/yr. The standard was first established in 1974 for tritium at the 20,000 pCi/L. In 1991, the EPA reviewed new data and concluded that a tritium concentration of 60,900 pCi/L would yield a 4 mrem per year dose, however, EPA kept the 20,000 pCi/L value for tritium in its latest regulations. (EPA 1974) Another example set forth by the NRC establishes tritium occupational ingestion and inhalation limits along with effluent concentration limits for "the assessment and control of dose to the public, particularly in the implementation of the provisions of § 20.1302. The concentration values given in Columns 1 and 2 of Table 2 are equivalent to the radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a total effective dose equivalent of 0.05 rem (50 millirem or 0.5 millisieverts)." (NRC 1995) The effluent concentration limit for tritium in air is set at 1×10^{-7} μCi ml^{-1}.

The NRC and EPA have established layers of radiation protection to achieve their mission of safety for the environment, radiation workers, and all other members of the public. Standards are established and designed to limit the quantity of effluents released and limit the exposure of vulnerable populations. To accomplish the goals set forth in these layers, regulatory bodies require surveillance programs to perform measurements of concentrations in environmental media. Surveillance programs are designed to monitor the regular release of HTO, measure any accidental discharges, and, in so doing, validate the generating facilities effort to remain compliant with federal and state standards. The following examples are a few of the many rules set forth by the regulatory agencies. The regulatory bodies usually develop rules based on the recommendations of professional scientific organizations which establish standards through the research and experimentation of peer reviewed scientific literature (i.e. National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP)).

- An ALARA objective for an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 millirems to the total body or 10 millirems to any organ (Appendix I to 10 CFR50).
- EPA dose limits related to nuclear power are established at 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of an individual member of the public (40CFR190 and 10CFR20.1301(e)).
- 100 mrem $year^{-1}$ limit for general members of the public (10CFR20.1301(a)(1)).

HTO sampling near nuclear reactors and other facilities licensed by the NRC is required in part to verify compliance to exposure (10CFR20.1301) and contamination (66FR76708) standards imposed by the EPA and NRC. HTO as it is rapidly dispersed into the environment emitting low energy betas, and can be collected using desiccant material, such as MS. After desorption from the desiccant, the collected sample’s activity is usually measured with a Liquid

Scintillation Counter (LSC). The sample's activity along with data collected during the sampling process is used to determine atmospheric HTO concentrations.

1.3 ^{3}H and Atmospheric HTO Sampling

1.3.1 Transport and Creation of ^{3}H

"Hydrogen is the most abundant element in the universe, comprising approximately 90% of the universe by weight." (CNSC 2009) Hydrogen is composed of one proton and one electron. Several forms of the hydrogen element exist. Deuterium (^{2}H) makes up about 0.02% of the natural hydrogen; ^{3}H, the only naturally occurring radioactive isotope of hydrogen, averages 10^{-18} percent of all hydrogen (ANL 2001). ^{3}H has a half-life of 12.32 years and emits low energy beta radiation (18.6 keV max, 5.7 keV average).

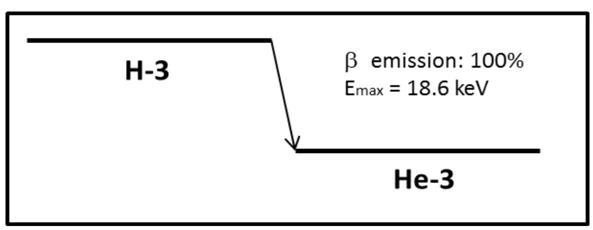

Figure 1.1 Tritium Decay Scheme (University of Toronto)

^{3}H is created naturally when high energy cosmic particles interact with the constituents of the upper atmosphere through nuclear absorption or by spallation reactions. (Eisenbud and Gesell 1997) ^{3}H is found as HTO in the liquid or vapor state as well as elemental tritiated gas (HT); organically bound tritium (OBT) is also present but not involved in the hydrological cycle.

(CNSC 2009). “Tritium exists in the atmosphere principally in the form of water vapor and precipitates in rain and snow. Like ^{14}C, ^{3}H is also produced in thermonuclear explosions, or in general as a byproduct of the fission process. These types of anthropogenic sources of tritium have increased the atmospheric content of tritium in a manner that will be discussed in a later chapter. The natural cosmic production rate of tritium is estimated (NCRP, 1979) to be about 0.19 atoms cm^{-2} s^{-1} corresponding to a steady-state global inventory of about 26 MCi (9.6×10^5 TBq).” (Eisenbud and Gesell 1997) The unit “atoms cm^{-2} s^{-1} is calculated from the cosmic ray flux (particles $second^{-1}$) and nuclear cross section data (Craig 1960) or by direct measurement with high altitude detectors measuring ^{3}H atoms production in specific volumes of atmosphere. (Teegarden 1967)

The INL Oversight Program, managed by the IDEQ, recorded maximum atmospheric HTO concentrations around the INL in 2017 at 0.88 ± 0.42 pCi m^{-3}. “All atmospheric tritium measurements for 2017 were much less than one percent of the concentration for compliance with federal regulations (40CFR61), 1,500 pCi m^{-3}. Tritium levels were at or near background levels at all locations.” (IDEQ 2017)

1.3.1.1 Anthropogenic Sources of ^{3}H

Man-made (anthropogenic) HTO can be generated in various ways including; boron (^{10}B) activation in light water reactors, and neutron absorption of lithium (^{6}Li) and helium (^{3}He) (Ojovan et al 2014). Anthropogenic ^{3}H is a byproduct of a nuclear reactor’s operation. ^{3}H can be purposefully generated for commercial and medical purposes (CNSC 2009) or for the maintenance of the nuclear weapons in the national stockpile. (NRC 2005) Anthropogenic contributions to HTO have increased the global inventory above natural concentrations. (Okada and Momoshima 1993)

HTO releases from regulated entities are common and expected, however unintended, or “off-normal” releases associated with either monitorable point source releases or fugitive/diffuse emission may increase the anticipated quantities of HTO released. “The annual production of fission-product tritium by a 1,000-MWe light-water reactor (Kouts and Long, 1973) is in the range of 15,000 to 25,000 Ci (560 to 930 TBq),” (Eisenbud and Gesell 1997) also “tritium production by neutron interaction with soluble boron can account for an additional 500 to 1,000 Ci (19 to37 TBq) per year.” (Eisenbud and Gesell 1997) The NRC and EPA require facilities that generate HTO to participate in surveillance programs and monitor the regular release of HTO effluents and discover/mitigate any unintended discharges (i.e. 10CFR20.1406, 10CFR50.36a, b and 49CFR190.10). The various HTO releases for different types of generating facilities are shown in Figure 1.2.

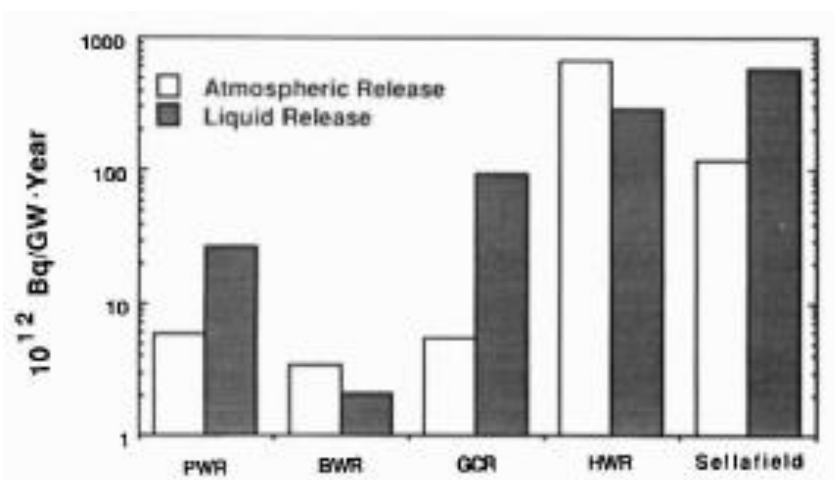

Figure 1.2 HTO Release Per Reactor Type (UNSCEAR 1988)

“Although tritium is constantly undergoing radioactive decay, which reduces the amount of tritium in the environment, it is also being generated by those processes discussed earlier. These competing processes of production and decay result in a dynamic worldwide inventory of tritium that has fluctuated over time and can be correlated with human activities, most notably the atmospheric testing of nuclear weapons” (HPS accessed on 21 October 2017). Man-made contributions of HTO into the environment have been declining the past few decades primarily due to international treaties banning atmospheric weapons testing (Partial Test Ban Treaty of 1963), arms reduction (Strategic Arms Reduction Treaty of 1991), and advancing technologies (CNSC 2010), ultimately leading to reduced global inventories of ^3H. Figure 1.3 shows average ^3H concentrations in precipitation in Vienna, Austria (representing the Northern Hemisphere) between 1955 and 1995. The large spikes in HTO concentration observed during the 1960’s reflect the consequences of various weapons testing programs (IAEA 2000).

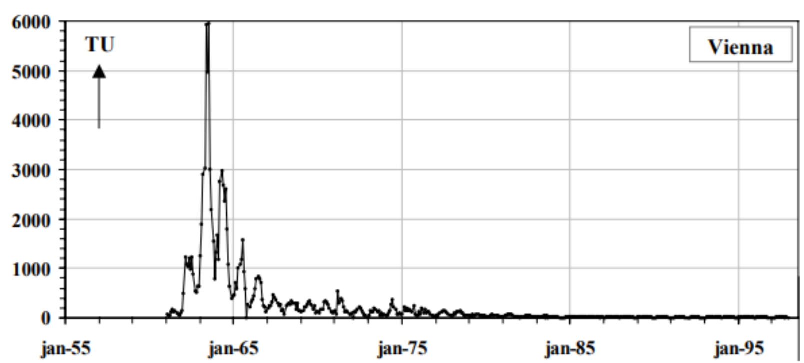

Figure 1.3 Tritium Concentrations in Precipitation (IAEA 2000)

^3H in environmental media is primarily monitored as HTO by water grab sampling or low-flow atmospheric water vapor collection with desiccant material. A Tritium Unit (TU) is 1 atom of tritium per 10^{18} atoms of hydrogen, 7.14 disintegrations per minute (DPM), or 0.119 Bq L^{-1}. (L'Annunziata 2012)

1.3.2 Distribution and Biological Effects of ^{3}H

Tritium as alluded to earlier follows the same transport and cycling principles as hydrogen (CNSC 2009). Seasonal variations can affect the amount of moisture present in the atmosphere. "The lack of significant isotopic effects or biomagnification means that tritium transport and cycling in the environment can be predicted based on transport processes, hydrogen content, and chemical transformation of hydrogen and its compounds in the environment." (Murphey 1993) Tritium will bind readily to oxygen, forming HTO; it can also chemically bind with organic material to create OBT. (Kim et al 2013) HTO will follow the hydrological cycle similarly to that of normal water throughout the hydrosphere and is taken into the body in the same manner. (CNSC 2009) "Incorporation of tritiated water into the human body can occur by three pathways: 1) tritiated water vapor in air can be taken into the body via the lung through respiration, 2) tritium in fluids and foods can be ingested orally and absorbed through the gastrointestinal tract, and 3) tritiated water or its vapor can be absorbed through the skin." (Okada and Momoshima 1993) Once ingested, HTO will have almost a 100% uptake, compared to that of the inhalation of tritiated gas, with only a 0.005% uptake (Eisenbud and Gesell 1997). Uptake is an important factor when determining an internal dose. "In doses calculated prospectively, intake of each radionuclide is estimated as the product of its concentration in air, food, water, or other medium and the quantity of such medium taken into the body through breathing, ingestion, or skin absorption. The absorption (uptake), distribution, and retention of a radionuclide is estimated from biokinetic models of the element in humans." (National Research Council 1994)

HTO will distribute uniformly throughout the body like water and is expected to uniformly expose the whole body (UNSCEAR 2016). The time from intake to excretion, or the biological half-life (T_B), for HTO is roughly 10 days (ICRP 1982). "The committed dose from HTO already in the body can be reduced by increasing the individual's water intake rate, which in effect reduces the effective half-life of tritium in the body." (IAEA 1991) The IAEA report continues saying that "a dose reduction of up to 50% can be realistically achieved and that the marginal benefit beyond a treatment period of 10 d is minimal." (IAEA 1991)

The low energy beta radiation from HTO has very limited penetrating power and is only considered a risk once taken into the body. (Okada and Momoshima 1993). The unit of equivalent dose expressed in units of rem considers the amount of energy deposited into tissue and the associated quality factors. This kind of factor is combined by multiplication with the absorbed dose (rad or gray) to obtain a quantity that expresses on a common scale for all ionizing radiation, the biological damage (rem or Sievert) to the exposed tissue." (HPS accessed on 21 October 2017) The quality factor for beta radiation and the updated term "radiation weighting factor", is equal to 1 as per ICRP 26, 30, and 60; this is the standard incorporated by the NRC (10CFR20.1004).

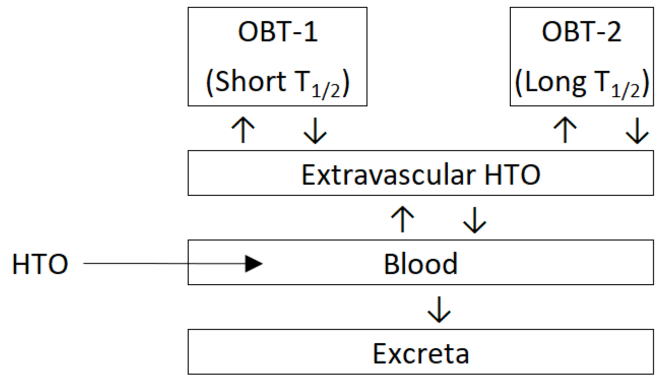

Figure 1.4 ICRP 78 Tritium Biokinetic Model (ICRP 1997)

Knowledge of the health effects for HTO is limited to data obtained from animal experimentation and in-vivo cellular exposures and have only been performed under acute exposure conditions. (Okada and Momoshima 1993) Information from the direct health risks from human exposures to tritium is not available, however excess risk was estimated using available human epidemiological data incorporating the appropriate dose-rate effectiveness and relative biological effectiveness (RBE) factors. (Straume 1993) "The resultant lifetime risk coefficients for low-level exposure[1] to tritiated water are as follows. The most probable risk at the 50th percentile for cancer mortality risk coefficient is currently thought to be 81 x 10^{-6} mGy^{-1} and at the 90% confidence interval the risk coefficient is 38 to 185 x 10^{-6} mGy^{-1}. For genetic effects in the first generation after exposure the risk is 7.9 x 10^{-6} mGy^{-1}, with a 90% confidence interval of 3.8 to 16.3 x 10^{-6} mGy^{-1}." (Straume 1993). To put this into perspective, for gamma radiation, 200 dental x-rays is equal to 1 millisievert (equivalent to 1 milligray (mGy) for beta

[1] Describing exposure as "low-level", it is assuming that the dose received is far too small to produce acute radiation damage of clinical significance. The subsequent chronic type of exposure may present an increased stochastic risk to diseases such as cancer thought to be sometimes radiogenic in origin.

and gamma radiation with a quality factor of 1). (Radiological Society of North America 2019) A risk factor of 1 x 10^{-6} mGy^{-1} for beta radiation equates to a one in a million chance.

1.3.3 ^{3}H Surveillance and Sampling

The IDEQ method of HTO surveillance in ambient air incorporates desiccant, namely MS, to adsorb HTO vapor from air samples that are pumped through the desiccant as seen in figure 1.5 (Lewis 2014). Airborne HTO is sampled concurrently with water (H_2O) and would identify if HTO were released by a generating facility.

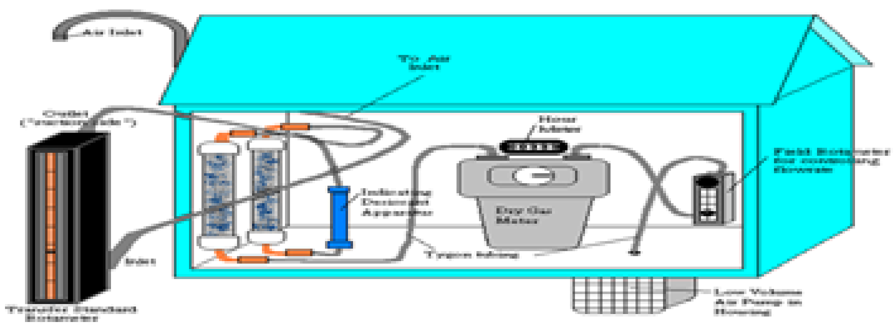

Figure 1.5 INL Oversight atmospheric moisture sample (Lewis 2014)

HTO is collected along with atmospheric moisture using a hydrophilic desiccant material. Air is drawn through the desiccant chambers with the use of low flow vacuum pumps. Desiccants have default sampling limits due to their finite capacity to adsorb water*[2]. Sampling

[2] Honeywell UOP - 25 E. Algonquin Road (Bldg. A), P.O. Box 5017, Des Plaines, IL 60017-5017

periods are limited to avoid saturating the desiccant, periods typically range from a week to a couple of months vary due to seasonal changes in climate (CNSC 2009), as can be observed during a review of historical sampling data. Dry gas meters and rotameters are used to establish the flow rate and measure the sample volume. Atmospheric HTO concentrations are derived from the mass of the moisture collected in the MS, the tritium activity concentration in the moisture, and the volume of air sampled.

1.3.3.1 HTO Sampling Variables

The uncertainty associated with HTO measurements may be better realized by understanding how MS performance varies in certain climate conditions. The following paragraphs explain how temperature and humidity impact desiccant (MS) and uncertainty in the HTO sampling process.

1.3.3.2 Temperature and Humidity

Temperature can directly affect many variables involved with HTO sampling, such as relative humidity (RH%) and vapor pressure. Saturation occurs when the desiccant can no longer adsorb water allowing for the unmonitored pass-through of sample. (Garg and Ruthven 1973) If this occurs final weight measurements will not account for moisture passed through the desiccant due to saturation. (Farag et al 2011) The IDEQ uses a small indicating column placed between the two collection columns to avoid this issue.

Better collection performance can be achieved by decreasing the gas flow rate, increasing the MS bed length, or decreasing the MS bed temperature. (Farag et al 2011) The duration of sampling should consider climate and seasonal weather trends. Higher air temperatures increase vapor pressure and allows for higher water vapor concentrations in the air; these conditions will saturate desiccant beds faster. (Farag et al 2011) Although higher MS column temperatures increase adsorption rates in desiccant materials, the ability of desiccant beds to collect and retain sample may increase. (Farag et al 2011)

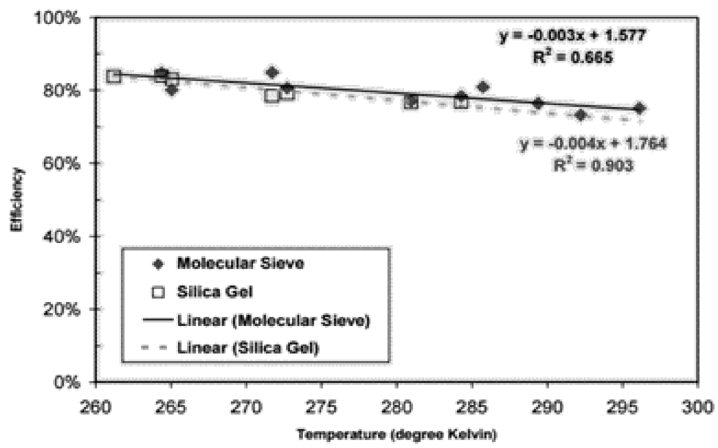

Figure 1.6 Collection/retention efficiencies as a function of temperature (Paulus et al 2003)

"As observed in previous studies, the atmospheric moisture collection efficiency for silica gel and molecular sieve decreases as the ambient temperatures increase. When the ambient temperatures increase, the likelihood that there is some loss of moisture or sample breakthrough increases." (Paulus et al 2003) This collection efficiency can be observed in Figure 1.6. The collection efficiency of MS as used in this research, is defined as the ratio of the amount of water vapor adsorbed by the MS compared to the total water vapor which could have been adsorbed. The collection efficiency can be calculated by measuring the moisture content of the sample before entering the desiccant column and again after the sample leaves the desiccant column. The two values are then compared to determine the amount of water vapor adsorbed by the MS. Elevated temperatures may require larger quantities of desiccant, or shortened sampling periods in order to avoid breakthrough. Conversely, lower temperatures may require longer sampling periods due to the limited water vapor present in the air. As shown in Figure 1.7, as the water inlet vapor concentration increases so does the amount of water vapor removed.

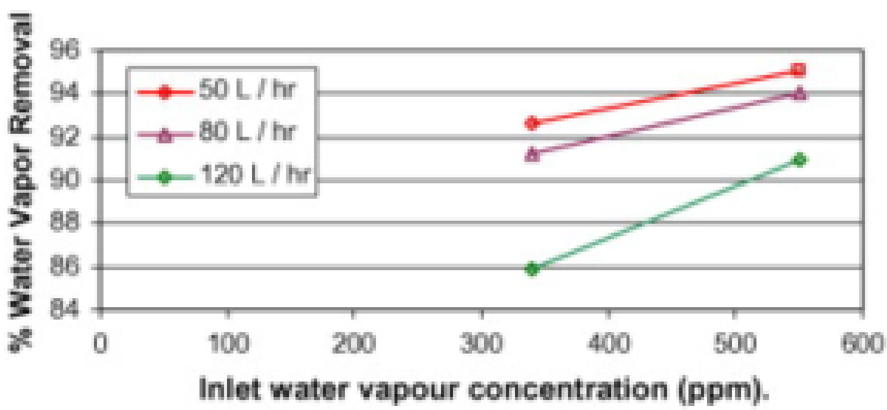

Figure 1.7 Water vapor removal vs. water vapor concentration (Farag et al 2011)

1.3.3.3 Molecular Sieve

The collection/retention potential for MS remains relatively constant up to 200° F, as demonstrated by Paulus et al 2003. MS can reduce moisture content down to concentrations of 1 part per million (ppm)[3]. MS is designed to “trap” molecules that have smaller effective diameters

[3] Honeywell UOP - 25 E. Algonquin Road (Bldg. A), P.O. Box 5017, Des Plaines, IL 60017-5017

than the pore size of the MS, excluding larger molecules. MS pore diameters are designated in units of angstroms (Å) (Å = 1x10^{-10} meters). The most common MS for dehydration purposes are 3Å and 4Å, representing pore sizes of 3 x 10^{-10} meters and 4 x 10^{-10} meters.

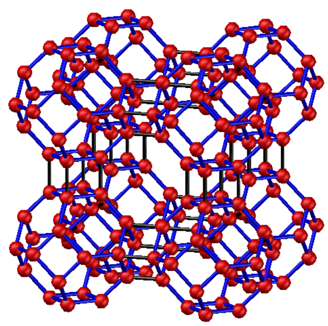

Figure 1.8 Structure Model for 4A Molecular Sieve (Zhang 2013)

MS is composed of zeolites, or crystalline aluminosilicates. This material has a high affinity for polar molecules (i.e. water) due to the presence of cations, like sodium (4A) and potassium (3A). (Armarego and Chai 2009) The effectiveness of MS as an adsorbent is enhanced by the polarization described by Armarego and Chai. "At 25^{o} (C) and a relative humidity of 2%, type 5A molecular sieve (beads) adsorbs 18% by weight of water, whereas for silica gel and alumina the adsorption fraction by weight are 3.5% and 2.5% respectively. Even at 100^{o} (C) and a relative humidity of 1.3%, molecular sieve (beads) adsorbs about 15% (water) by weight of water." (Armarego and Chai 2009) There are a few difficulties when working with MS:

1. MS will adsorb less water per unit weight compared to silica gel, another common desiccant. The equilibrium capacity is the capacity of a desiccant to adsorb water in terms of mass of water adsorbed per mass of desiccant (expressed as weight percent)

(Mokhatab et al 2015); MS equilibrium capacity will vary around 20 to 25% at ideal temperature and humidity. “The adsorption capacity of molecular sieve (beads tend to be) less than that of silica gel. For example, at 70% RH and 25° C, a molecular sieve can adsorb approximately 22% of the available moisture, while silica gel can adsorb approximately 32% of moisture at the same condition.” (Chen et al 2017)

2. MS is synthetically made and will have a higher cost per unit volume compared to silica gel, which is manufactured using a cheaper sodium silicate and sulfuric acid.[4]

1.4 Uncertainty

The information in the following sections come from the IDEQ and Idaho State University’s (ISU) Environmental Monitoring Laboratory (EML) practices and procedures (Lewis 2014). The following paragraphs detail how Type A and Type B uncertainty would be derived with HTO sampling. Type A uncertainty is an “evaluation of a component of measurement uncertainty by statistical analysis of measured quantity values obtained under defined measurement conditions.” (ISO 2008) Where Type B uncertainty is an “evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty.” (ISO 2008) Type B uncertainty includes uncertainty derived from calibration certificates, class specifications for a measuring instrument, and published/certified reference material.

[4] Sorbent Systems. Online Presence of IMPAK Corporation. 13700 S Broadway Los Angeles, CA 90061

1.4.1 Quantifying Uncertainty in Sample Collection

Uncertainty in environmental HTO sampling has been sorted into two main categories for this research: volume of air sampled, and volume of moisture collected.

Air Volume

Air volume can be measured with the use of dry gas or mass flow meters. The uncertainty associated with the measurements made by these meters are commonly provided by the manufacturer; these uncertainties are reliable so long as manufacture recommendations are followed (i.e. calibration frequency, flow rates, temperature ranges). Uncertainties for these air volume meters can range as low as 1.5 to 2.0%[5]. Dry gas meters need to be corrected for air pressure variations as they are calibrated for standard climate conditions (i.e. 20^{o}C and 1 atm) (40CFR60 Appx A-1, Method 2A). The IDEQ incorporates this into their procedures as detailed in equation 1.1.

$$V_c = V_{air} * \left(\frac{25.5\ inHg}{29.9\ inHg}\right) * \left(\frac{0.02832\ m^3}{ft^3}\right) \qquad \textbf{(1.1)}$$

Where V_c is the corrected volume of air sampled (m^3) and V_{air} is the uncorrected volume of air sampled (ft^3). The air pressure at sea level (29.9 inHg) is corrected to the average pressure seen in East Idaho (25.5 inHg). This is then multiplied by the conversion factor from ft^3 to m^3.

[5] Omega Engineering Inc. 800 Connecticut Ave. Suite 5N01, Norwalk, CT 06854, USA.

Valued rotameters are used to control flow rates and can also be applied as a secondary source of air volume validation. Rotameters are simple machines installed in the process line that incorporates "a freely moving float finding equilibrium in a tapered tube." (Dillon 2010) The equilibrium corresponds to a flow rate scale on the tube, which is read by the user. Rotameters require no external power supply, are simple to install and maintain, and will produce a minimal pressure drop in the process line. (Dillon 2010) The uncertainty associated with rotameters range between 1 and 20% depending on accuracy class defined in the VDI/VDE guideline 3513 (VDI 2014).

Sample Volume

Currently, the IDEQ derives sample water volume from the mass gained by the MS during the sampling period. Ideally, the total volume of water collected would be correlated to the adsorptive capabilities of the MS and the total sample available to adsorb. The mass gained by the MS during sampling is used to derive atmospheric HTO concentration by comparing this value with the volume of air sampled and the activity measured with the LSC as per equation 1.2. A review of the available historical sampling data found 9 instances out of 464 where the differences in recorded initial and final weights of the MS subtracted from the distillate retrieved from the MS were negative. This data can be referenced in the analysis and discussion section, Table 3.1, of this report. The negative number suggests that more liquid was purged from the MS than was collected during the sampling period or during some sampling periods the moisture is so low, that the quantity of moisture collected is below the sensitivity of this collection procedure. This is an area where unaccounted for uncertainty may arise.

To improve these measurements and provide more sensitivity, an inline hygrometer could provide an accurate representation of the environment that the MS was sampling; a collection efficiency factor could then be derived. The derived collection efficiencies could estimate MS performance based off predicted weather conditions. The collection efficiency would then be factored into the mass gained by the MS. Atmospheric HTO concentrations would then be representative of the unaccounted-for moisture potentially missed by the MS sampling procedure.

1.4.2 Quantifying Uncertainty in Sample Analysis

Uncertainty within the laboratory has been organized into two main categories for this research; sample retrieval and sample preparation/analysis. The following paragraphs detail laboratory materials and practices and their contributions to uncertainty.

Sample Retrieval

MS is taken from the sample station, sealed, and weighed at the laboratory. Digital analytical balances are used to weigh the samples; these are precise instruments with very great sensitivity with corresponding tolerances or uncertainties ranging between ± 0.01 milligrams[6]. Weight measurements are made before and after the sampling period to help determine how much moisture was adsorbed by the sample during the measurement process. Moisture from the MS is driven off until enough sample is collected and prepared for analysis; this is an area where

[6] Mettler-Toledo, LLC, 1900 Polaris Parkway, Columbus, OH 43240

unrealized uncertainty may originate (the process of purging the MS is detailed later in the methods section). It is assumed that the amount of liquid driven off the MS comes directly from the moisture collected from the sampling process; the weight gained (grams) relates to the volume of moisture collected (milliliters). This assumption may discount variable collection efficiencies and pre-existing moisture collected from the storage and laboratory environment by the MS beads prior to field deployment. MS is an efficient dehydrator and may inadvertently adsorb moisture before the sampling process. This level of pre-existing water is currently assumed to be negligible. However, for example, consider sample OP132HTR03 where the starting mass of MS was 1549.3 grams and ended with 1589.4 grams. The mass gained during the sampling process was 40.1 grams, but 51.6 grams of distillate was retrieved; for this sample, there is 11.5 grams, or 22%, coming from unaccounted for sources, contributes to greater uncertainty in final atmospheric concentrations.

Sample Preparation and Analysis

Once the sample has been retrieved from the MS, it is prepared for analysis in an LSC. Sample and LSC cocktail are transferred to the LSC vials via transfer pipettes. Class A 10-ml pipettes are required by ATSM International to have tolerances of no greater than ± 0.02 ml. The LSC establishes a counting efficiency each counting cycle. The LSC uses ^{3}H and ^{14}C calibration standards (STD) to verify operation integrity, and National Institute of Standards and Technology (NIST) traceable liquid ^{3}H STDs to develop a counting efficiency comparing the known activity of the decay corrected NIST standard versus the counts recorded by the LSC, creating a secondary calibration traceable to NIST.

1.5 Determination of Atmospheric HTO concentrations

Deriving atmospheric moisture concentrations combines data from sampling and analysis into an activity per unit volume. The expression for atmospheric HTO concentration is:

$$C(\,^{3}HAir) = \left(\frac{C_m * W}{F * T}\right) \qquad \textbf{(1.2)}$$

Where C(^{3}H Air) is the atmospheric HTO concentration (pCi ml^{-1}), C_m is the activity concentration detected by the LSC (pCi ml^{-1}), W is the volume of water vapor collected by the MS (ml), T is the sampling period (min) and F is the sampling flow rate (ml min^{-1}). The total volume of air is directly measured by the gas meter and is representative of the flow rate and sampling period. One focus of this report is to research variable W and provide an estimate of uncertainty that may be currently unrealized.

1.5.1 Sampling Period and Flow Rate

The sampling period, variable T, is recorded by subtracting the stop date and time from the starting date and time. These sampling period records are accurate up to the minute. The flow rate, variable F, is derived using rotameters. The IDEQ compares two field rotameters, a field rotameter and a transfer standard rotameter, to verify flow rate. A dry gas meter is used to secondarily verify flow rate, measuring volume during a specified sampling interval to derive flow rate and confirming the validity of the sampling data. The volume of air derived from flow rate and time is also compared to that of the volume measured by the dry gas meter after sampling is finished. The IDEQ uses the dry gas meter values in final HTO measurements.

1.5.2 Sample Volume

The volume of absorbed water vapor collected, or the change in mass of the MS, is derived gravimetrically. The initial weight of the MS is recorded before sampling begins and again after sampling has ended. The change in mass should also consider other variables such as MS collection efficiency.

Absolute Humidity (AH) is derived from temperature and air pressure and may be used in the derivation of the MS collection efficiency. The collection efficiency is determined in this research by either comparing the water vapor content available to adsorb in the sampled air and the amount of weight gained by the MS during the sampling process, or by direct measurement with a hygrometer before and after the sample passes through the desiccant column. AH is derived as follows in equation 1.3 (Mander 2012):

$$AH = \frac{6.112 * e^{\left(\frac{a*T}{T+b}\right)} * RH\% * 2.1674}{273.15+T} \tag{1.3}$$

Where AH is absolute humidity (g m^{-3}) measuring the total amount of water vapor available in the air, RH% is the percentage relative humidity. RH measures the moisture relative to the maximum moisture the air can hold at that temperature. T is the temperature (^{o}C), a and b are the Tetens' coefficients which equal 17.27 and 237.3 respectively (Mander 2012). The Tetens' equation, named after its creator, a German meteorologist, is used to calculate the saturation vapor pressure of water over liquid, detailing the relationship between temperature and partial pressure of water vapor. From this relationship between temperature and vapor pressure, AH can be derived. (Tetens 1930). These coefficients are empirically derived from earlier works, “Magnus (1844) made a very careful set of measurements of the equilibrium vapor pressure of water, which he desired to fit with a usable equation.” (Lawrence 2005). Tetens updated this formula in 1930. The value 2.1674 has been generated from combining the molecular weight of water (18.02 kg $mole^{-1}$) divided by the product of the ideal gas law constant (0.08314 L bar mol^{-1} K^{-1}) multiplied by 100. The saturation water vapor pressure is an empirical coefficient, a calibration constant, at 6.112 (mb) and is used in calculating vapor pressure. (Mander 2012)

A valued rotameter is used by the IDEQ to control the flow rate at “Standard Cubic Feet per Hour” (SCFH), this is the flow relative to standard conditions (14.7 psi, 68 degrees Fahrenheit, 36% RH, and 0.075 lbs. ft^{-3}) (Deziel 2018) This expressions units are converted from SCFH to “Actual Cubic Feet per Minute” (ACFM) or just CFM as detailed in equation 1.4:

$$Flow\ Rate = \left(\left(\frac{SCFH}{60}\right) * \left(\frac{psi_s}{psi_a}\right) * \left(\frac{T_R}{528}\right)\right) * \left(\frac{0.0283\ m^3}{ft^3}\right) \qquad \textbf{(1.4)}$$

Where the flow rate ($m^3\ min^{-1}$), psi_s is the standard pressure, psi_a is the actual pressure during sampling, and T_R is the temperature in Rankine. (Deziel 2018) This will convert SCFH at standard conditions to $m^3\ min^{-1}$ necessary for the integration of experimental and historical sampling data. The IDEQ uses the dry gas meter volume measurements in final atmospheric HTO calculations, however equation 1.4 will be useful in experimental sampling.

1.5.3 HTO Analysis

To determine the activity of an HTO sample, the LSC is used to measure background (BKG) levels, determine a counting efficiency, and derive a confidence interval (CI). This process will provide an estimation of uncertainty correlating to each measured HTO value from the LSC.

The counting efficiency of an LSC is the ratio of the machine's ability to detect events (counts) compared to the quantity of DPM that should produce events from a known activity. The counting efficiency will provide data to allow a conversion from detected counts to activity (CPM →DPM). Counting efficiency is:

$$E = \left(\frac{S-B}{D}\right) \quad \textbf{(1.5)}$$

Where E is the counting efficiency, S is the counts per minute (CPM) of the NIST traceable standard, B is the LSC's BKG (CPM), and D is the decay corrected activity of the NIST traceable standard (DPM). After the counting efficiency is established, the net count rate from the LSC is converted to activity.

Since radioactive decay is a random process and radiation detection instruments may not record every decay, there is no guarantee that the sample's true activity is measured. (Turner et al 2012) "The standard deviation for a net CPM can be expressed as the square root of the sum of the CPM divided by counting time of sample, and the CPM divided by the counting time of the background."[7] One standard deviation will provide a confidence interval of 68%. Applying a factor of 1.96 will report two standard deviations, or a 95% CI, meaning 95% of the time the interval will encompass the true value.(Currie 1968) The counting efficiency is derived along with a CI using the net sample count rate and BKG count rates to establish a degree of certainty that the sample's true activity lies somewhere between the measured values, incorporating counting efficiency and upper and lower bounds of the CI. The CI in which there is a 95% probability that the true activity lies somewhere between the upper and lower bounds is derived by the following in equation 1.6 (Currie 1968) for an unpaired sample:

$$E95 = \pm 1.96 * \sqrt{\left(\frac{C_S}{T}\right) + \left(\frac{B}{T}\right)} \quad \textbf{(1.6)}$$

Where E95 is the uncertainty in the net count rate at the 95% CI, C_s is the gross LSC sample count, B is the BKG (CPM), and T is the LSC's counting time (min).

The sample's activity concentration is then determined using the LSC's sample volume, counting efficiency, and net sample count rate (CPM) which is measured by the LSC. Concentration values are incorporated into equation 1.2 and used to determine final atmospheric HTO concentrations. The expression for determining LSC sample HTO activity concentrations is:

$$C_m = \frac{C_S - B}{\varepsilon * V * K} \quad \textbf{(1.7)}$$

[7] Perkins Elmer 940 Winter St. Waltham, Massachusetts 02451 United States

Where C_m is the HTO activity concentration (pCi ml^{-1}), C_s is the gross LSC sample counts, B is the LSC's BKG (CPM), ε is the counting efficiency for the LSC, V is the LSC sample's volume, and K is the conversion constant (2.22 DPM pCi^{-1}).

Chapter 2: Methods and Materials

2.1 Review of Historical Data

Historical data was drawn from the IDEQ HTO sampling as part of their INL Oversight Program for the years 2012 through 2014; subsequent analysis of the sampling data was provided by the EML.

The data sets were organized and recorded by the IDEQ geographically by location, and chronologically by sampling start date; other historical data recorded by the IDEQ used in this study includes sampling duration, MS mass changes, air volume sampled, and amount of distillate retrieved. This data can be referenced in Appendix A – IDEQ Sampling 2012 through 2014. A total of eleven locations were sampled. Historical climate data was provided by Weather Underground[8] for ease of transcription and verified using the University of Utah's[9] MesoWest meteorological network. Weather Underground provided average monthly temperatures and RH% of the general area at each sampling location. Historical data sets were consolidated and reviewed to better understand how temperature, humidity, and MS affects the sampling process.

The distillate retrieved by the IDEQ was collected from the MS as detailed in section 2.3; the collection data and distillate were transferred to the EML for preparation and analysis. This data can be referenced in Appendix A – HTO Analysis and Uncertainty 2012 through 2014.

The sampling and analysis data from the IDEQ and EML were consolidated into Microsoft Excel[10] and grouped according to sample location and sorted chronologically

[8] The Weather Company, an IBM business, 1001 Summit Boulevard, Floor 20, Brookhaven, GA, USA 30319
[9] Atmospheric Sciences William Browning Building 135 S 1460 E, Room 819 Salt Lake City, UT 84112-0102
[10] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

according to the sampling start date. Groups related to humidity, temperature, and MS performance were identified. The data were analyzed, and outliers were designated according to the following parameters;

1. The average flow rate (m^3 min^{-1}), days collected, corrected air volume (m^3), and LSC HTO concentration (pCi ml^{-1}) results were individually compared to the average AH (g m^{-3}) of the sampling period.
    a. The stop time was subtracted from the start time to calculate the sampling duration in days.
    b. The final dry gas meter reading was subtracted from the initial reading to calculate sampled air volume in m^3 and corrected for air pressure as per equation 1.1
        i. The corrected air volume was divided by the total sampling time to determine a flow rate.
    c. The final MS weight reading was subtracted from the initial reading to calculate mass gained in grams.
    d. The LSC concentration data were taken directly from the EML analysis
    e. AH was derived from the temperature and RH% data using equation 1.3
    f. The Excel[11] function =PEARSON was used to calculate magnitude of correlation between the variables.
        i. A Pearson Correlation Coefficient (PCC) between -1.0 to -0.5 and 0.5 to 1.0 indicates a strong positive or negative relationship respectively. (Laerd accessed on 16 June 2019)

[11] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

2. The total volume of air was multiplied by the average AH during the sampling period, deriving a theoretical volume of moisture (g) that passed by the MS during the sampling period.
   a. The flow rate was multiplied by AH deriving the total amount of water vapor theoretically sampled.
   b. The measured mass gained by the MS during the sampling period was divided by the theoretical volume of water vapor that was sampled deriving a unitless collection efficiency.
   c. The excel[12] function =PEARSON was used to calculate the magnitude of correlation between the collection efficiency and average flow rate, days collected, air volume, and LSC HTO concentration per recorded sample.
      i. A PCC between -1.0 to -0.5 and 0.5 to 1.0 indicates a strong positive or negative relationship respectively. (Laerd accessed on 16 June 2019)
3. Sample distillate data from the MS was compared to that of the mass gained by the MS during the sampling period. If the distillate retrieved was greater than the mass gained, the data point was considered an outlier.
4. Samples analyzed by the EML to have HTO concentrations above the LSC's minimum detectable concentration (MDC) were grouped together. Steps 1 through 2 were repeated, and the results were compared to the IDEQ's reported HTO concentrations for a determination of correlation based off positive results.

[12] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

2.2 Central Facilities Area (CFA) Water Sampling

A sample of water obtained from CFA inside the INL, which historically contains slightly elevated levels of HTO (below the EPA limit of 2.0 x 10^4 pCi L^{-1}) was sampled in ISU's Nuclear Engineering Laboratory in the basement of the Lillibridge Engineering Building.

CFA water was placed inside a 55-gallon drum and sealed to create a closed environment. The lid of the drum was fitted with an inlet and exhaust port to isolate and direct airflow. PVC tubing connected the sampling system. An inlet fitting on the inside of the drum's lid was connected to the PVC tubing and placed at the bottom of the CFA water inside the drum. A Thomas Industries[13] low flow vacuum pump with a max flow rate of 0.76 CFM was used to create negative pressure in the drum's head space, sparging air through the CFA water to volatilize HTO from it. An increase in the sample's volatilization rate is attained under aeration conditions. (Helfer et al 2012) A Sper Scientific[14] SD data logging hygrometer model 800021 was used to measure temperature and humidity; It has an accuracy of ± 3% for RH from 5 to 95% and 0.8 °C accuracy for temperature from 0 to 50 °C. The probe of the hygrometer was placed directly in the sampling line. A Key Instruments[15] rotameter was set at a flow rate of 4 SCFH before entering the desiccant column with an accuracy of ± 4%. The rotameters functionality was verified before sampling by comparing the flow rate of the rotameter with the use of a control rotameter, controlling the flow rate at 1 SCFH, verifying the flow rate to be within 10% of the control rotameter. The drum's headspace air passed through a desiccant column, where moisture was adsorbed by the MS. Type 4A Sigma-Aldrich[16] MS beads were

[13] Thomas by Gardner Denver 1419 Illinois Ave Sheboygan WI 53081
[14] Sper Scientific 8281 E. Evans Rd. Suite #103 Scottsdale, AZ 85260
[15] Brooks Instruments 407 West Vine Street Hatfield PA 19440
[16] Sigma-Aldrich PO Box 14508 St. Louis, MO 63178

used to collect the volatilized CFA sample. At the end of sampling, before the MS was removed, the hygrometer was moved to behind the desiccant column in the process line to record the RH% after the sampled passed through the desiccant column in support of the derivation of the MS collection efficiency for total water vapor. The MS was prepared for distillation; the distillate was obtained as detailed in section 2.3. The distillate was prepared and analyzed as detailed in section 2.4.

This sampling process was repeated running ambient air through fresh MS in the laboratory instead of the CFA water. This approach allowed for a background measurement to which the CFA samples could be compared.

2.3 MS Preparation and Retrieval

The MS was prepared by first measuring approximately 350 to 400 grams of MS on a Denver Instruments[17] high precision analytical balance, model TP214, with an accuracy ± 0.1 mg, then placed into the desiccant column beds. This amount of MS was estimated to be enough to prevent breakthrough during the sampling period under most climate conditions. This amount was calculated using the manufacturer specified equilibrium capacity at 23% per unit weight. This allowed for an estimated maximum 80 to 90 ml of sample to be collected. Samples ran continuously for a period between 2 to 4 weeks.

At the end of each sampling period, the MS was removed from the column and reweighed on the high precision analytical balance to determine how much mass had

[17] Denver Instrument 5 Orville Dr. Bohemia, NY 11716

accumulated during the sampling period. The accumulated mass was compared to that of the total amount of vapor that passed through the desiccant column, recorded by the hygrometer, to determine a collection efficiency factor for the MS.

Finished samples were sealed and sent to the Environmental Assessment Laboratory (EAL). The MS was placed into a 250-ml round bottom glass flask. The flask was wrapped in electrical heating tape on a medium heat as to not fracture the glass. The MS was distilled, desorbing the vapor sample from the MS. The sample ran through a graham condenser and the liquid water was collected in an LSC vial at the bottom; cool water ran through the inner coil. Approximately 20 to 30 ml of sample was collected in an LSC vial and prepped for analysis by the EAL. The MS was weighed before and after the sample was desorbed from the MS to compare the final weight loss in grams to that of the sample collected in milliliters. All laboratory glassware, heating elements, and materials for LSC preparation were supplied by the EAL.

2.4 Sample Analysis

The samples were then analyzed using an LSC, this task was performed by the EAL. Nine milliliters of each sample were transferred into a 20-ml LSC vial using a 10-ml Class A transfer pipette (± 0.02 ml). The remaining 11 ml was filled with scintillation cocktail using an analog-adjustable bottle top dispenser. The LSC sample vials were closed, labeled, and shaken to ensure complete mixing. A total of 3 STD and 3 BKG samples were placed in the front, middle and end of the sample population. After the samples were finished counting, the data were used to construct a counting efficiency, 95% CI, and sample and environmental HTO concentrations using equations 1.5, 1.6, 1.7 and 1.2 respectively.

2.5 Data Analysis and Uncertainty Derivation

The temperature and RH% data obtained from the hygrometer was consolidated into Microsoft Excel[18]. The total volume of water vapor sampled was calculated using equation 2.1.

$$Total\ Vapor = AH * Flow\ Rate * Sample\ Duration \qquad \textbf{(2.1)}$$

Where the Total water vapor (g) is the total volume of water vapor sampled, AH (g m^{-3}) is the absolute humidity derived from the data collected by the hygrometer, flow rate (m^3 min^{-1}), as detailed in section 2.2, uses equation 1.4 to derive flow rate, sample duration (min) subtracts the starting sampling date from the end date. The mass gained by the molecular sieve during sampling was divided by the total amount of water vapor sampled creating an empirically derived collection efficiency. This method for determining collection efficiency (method 1) was compared to the flow rate, MS column mass, and sampling duration. The related data fields were individually compared and analyzed against the collection efficiency for a determination of correlation using the excel[19] function =PEARSON. The secondary method 2 for determining

[18] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399
[19] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

collection efficiency compared direct measurements of the hygrometer before and after entering the desiccant column.

The one sigma uncertainty associated within the historical sampling process is detailed by the IDEQ's sampling procedure SOP-002 (Ritter 2014) in equation 2.2.

$$\sigma_{C_{am}}^2 = \left(\frac{\partial C_{am}}{\partial \Delta m}\right)^2 * \sigma_{\Delta m}^2 + \left(\frac{\partial C_{am}}{\partial C_{moisture}}\right)^2 * \sigma_{C_{moisture}}^2 + \left(\frac{\partial C_{am}}{\partial V_{corrected}}\right)^2 * \sigma_{V_{corrected}}^2 \qquad \textbf{(2.2)}$$

Where C_{am} is the atmospheric tritium concentration (pCi m^{-3}), $C_{moisture}$ is the moisture tritium concentrations from the LSC (pCi ml^{-1}), $V_{corrected}$ is the temperature and pressure corrected volume of air from the dry gas meter (m^3), Δm is the change in the MS column weight (g) (Ritter 2014). MS collection efficiencies were implemented into Δm and adjust the total final weight gained by the MS during the sampling process. The uncertainty associated with MS collection efficiencies is detailed in equation 2.3.

$$\sigma_{\Delta m} = \sqrt{\sigma_{RH\%}^2 + \sigma_{Temp}^2 + \sigma_{V_{air\ volume}}^2 + \sigma_{V_m}^2} \qquad \textbf{(2.3)}$$

Where $\sigma_{\Delta m}$ is the uncertainty in the MS change in mass (g) which includes the uncertainty contributions from the climate data. The derived collection efficiencies were incorporated into the original atmospheric HTO concentrations reported by the IDEQ and reviewed for viability or inconsistencies. An uncertainty budget was created using equation 2.3.

Monthly average climate data values were obtained from Weather Underground which provided temperature and humidity data from the sampling locations. The average RH% and temperature values were used in the derivation of collection efficiencies. The temperature and humidity data points were averaged over the sampling period. A random sampling of the AH values derived from the temperature and humidity data were surveyed for accuracy of the climate information. The sampling plan is detailed in equation 2.4. (Lunt 2018)

$$n = (\frac{1.96\sigma}{W})^2 \qquad \textbf{(2.4)}$$

Where n is the sample size, 1.96 is the Z-score chosen to achieve a 95% coverage within the distribution, σ is the standard deviation, and W value which designates a level of acceptable error at 10%. (Lunt 2018) The randomized sample size from the population of historical sampling data were calculated to be 57.

Chapter 3: Analysis and Discussion

3.1 Review of Historical Data

The results from the comparison of variables with the IDEQ atmospheric HTO sampling directly related to humidity, temperature, and MS performance and their correlation within the sampling parameters is recorded in Table 3.1. The focus was to identify any trends or performance criteria for the MS and how it responds in differing climate conditions.

Table 3.1 Sampling and collection variables related to temperature, humidity, and MS performance and their correlation to AH

Variable	Average	StDev	PCC between variable and AH
AH (g m^{-3})	5.11	1.97	NA
Flow Rate (m^3 min^{-1})	3.96×10^{-4}	8.06×10^{-5}	0.25
Days Collected (d)	30.75	15.18	-0.52
Corrected Sample Volume (m^3)	16.89	7.48	-0.46
Concentration (pCi ml^{-1})	5.26×10^{-2}	7.02×10^{-2}	0.25

A PCC between -1.0 through -0.5 and 0.5 through 1.0 indicates a strong negative or positive relationship respectively. As shown in Table 3.1, the relationship between the collection period and AH has a strong negative correlation (PCC = -0.51). This agrees with the idea that the more water vapor available to adsorb, increased temperatures, and higher vapor pressures allow for better MS performance.

The derived collection efficiency based on historical sampling data were compared to other sampling variables in Table 3.2 and details the relationship between variables and their effect on the MS collection efficiency. The focus of this comparison was to derive a collection efficiency from the historical sampling data to determine if any of the sampling variables correlate to predictable changes in MS performance. As demonstrated in Table 3.2, there is no variable with strong negative or positive relationships in correlation with the derived collection efficiency.

Table 3.2 Comparison of MS collection efficiency and its relationship with sampling variables.

Variable	Average	StDev	PCC between variable and collection efficiency
Collection Efficiency	92.16	30.93	NA
AH (g m^{-3})	5.11	1.97	-0.31
Corrected Sample Volume (m^3)	16.89	7.48	-0.41
Days Collected (d)	30.75	15.18	-0.32
Flow Rate (m^3 min^{-1})	3.94×10^{-4}	7.20×10^{-5}	-0.06
AH * Flow (g min^{-1})	92.70	37.05	-0.71

As shown in Table 3.3, there were nine instances in which the amount of distillate purged from the MS after sampling (ml) was greater than the measured mass gain by the MS during the sampling period (g). This discrepancy suggests a presence of an unknown uncertainty contributor which currently is unaccounted for such as pre-existing moisture or co-collection of other gases or vapors.

Table 3.3 Samples where distillate retrieved was greater than the reported mass gain by the MS during the sampling period.

Sample ID	Start Date/Time	Stop Date/Time	Analysis Date	Days Collected	Start Column Mass	Stop Column Mass	Mass Gain (g)	Distillate (mL)	Mass After distillation (g)	Flow Rate (m^3)
OP142ATR02	4/3/2014	5/8/2014	07/31/14	34.99	1536.1	1596.6	60.5	66.8	-6.3	0.021
OP134ITR03	10/31/2013	11/21/2013	01/24/14	20.95	1486.1	1538.6	52.5	53.3	-0.8	0.023
OP134STR03	11/21/2013	1/2/2014	01/24/14	41.97	1498.7	1530.8	32.1	33.4	-1.3	0.015
OP141VTR03	2/27/2014	4/3/2014	04/29/14	34.96	1498.0	1544.4	46.4	47.9	-1.5	0.020
OP121VTR03	2/9/2012	3/13/2012	4/3/2012	33.05	1408.1	1445.1	37.0	41.2	-4.2	0.016
OP141HTR03	2/27/2014	4/3/2014	04/29/14	34.97	1520.6	1565.5	44.9	49.4	-4.5	0.018
OP143CTR03	7/31/2014	8/8/2014	09/25/14	7.95	1478.7	1526.4	47.7	56.1	-8.4	0.029
OP132HTR03	5/16/2013	6/4/2013	07/26/13	19.08	1549.3	1589.4	40.1	51.6	-11.5	0.021
OP141BTR03	3/12/2014	4/3/2014	04/29/14	22.00	1395.2	1428.7	33.5	45.0	-11.5	0.022

In a review of sample data where the LSC analysis of HTO activity concentration is greater than the MDC, there were no variables having a strong negative or positive relationship with the HTO activity concentration results as detailed in Table 3.4. The sampling location "Experimental Field Station" did show small increases in HTO concentrations above the MDC in 25 out of 58 samples analyzed. The mean HTO concentration and standard deviation of the sample from the "Experimental Sampling Location" was 0.148 ± 0.079 pCi ml^{-1} compared to the mean HTO concentration and the standard deviation of the entire sample population at 0.094 ± 0.080 pCi ml^{-1}; the elevated mean HTO concentration is still within two standard deviations from the mean of the entire population.

Table 3.4 HTO concentration and its relationship with sampling variables

Variable	Average	StDev	PCC between variable and HTO concentration
HTO Concentration	0.23	0.12	NA
Flow Rate (m^3 min^{-1})	0.239	3.20×10^{-3}	0.23
Corrected Sample Volume (m^3)	16.61	3.90	0.33
Mass gain (g)	77.72	15.71	0.19
Days Collected (d)	29.27	7.41	0.16
AH (g m^{-3})	6.51	2.00	-0.09
Collection Efficiency	68.13	19.82	-0.01

3.2 Experimental Sampling Results

The experiment was not designed to replicate the IDEQ's sampling method, but rather to access the feasibility and applicability of including a hygrometer into the process line and the utility of the data the hygrometer would provide in assessing final HTO measurements. The experiment then looked at whether a hygrometer could be included into the process line and if data could be recorded, collected, and used in the derivation of a collection efficiency. Also, a water sample with elevated HTO was used to see if changes in the MS collection efficiencies could account for differences in the LSC HTO results. The experimental data results can be found in Appendix C and is detailed in the following paragraphs.

It was determined that a hygrometer could easily be included into the sampling process and that the data could be utilized in establishing collection efficiencies; the hygrometer recorded and stored detailed temperature and humidity data of the sampled air on a memory card. Two methods for establishing collection efficiency were then considered, as detailed in section 2.5.

Method 1 provided insufficient data and was ineffective at reliably establishing collection efficiencies, however, the data collected did help support the idea that method 2 could effectively, and in real-time, determine collection efficiency. Method 2 is recommended in developing future collection efficiencies; however, this method requires using two hygrometers. Two hygrometers would be implemented in the field for data collection, being placed before and after the desiccant column to determine collection efficiencies and to quantify the amount of water vapor not collected by the MS.

The empirical collection efficiency derived using method 1 from experimental sampling was lower than the historical sampling data provided by the IDEQ (7.30 ± 0.14% vs 92.68 ± 32.86%). This reduction in collection efficiency is assumed to be attributed to the increased flow rates ($2.28 \times 10^{-3} \pm 6.53 \times 10^{-5}$ m^3 min^{-1} vs $3.9 \times 10^{-4} \pm 7.2 \times 10^{-5}$ m^3 min^{-1}) and smaller desiccant columns (383.00 ± 4.53 g vs 1,448.39 ± 48.70 g) leading to increased breakthrough and uncertainty in the MS collection efficiency towards the end of the sampling periods. The collection efficiencies from the experimental sampling could not be extrapolated and incorporated into the IDEQ data. Also, the meteorological data gathered from The Weather Underground[20] could not provide the same level of accuracy required for method 1 for determining collection efficiencies. If the collection efficiencies developed using method 1 were applied to the IDEQ data, the collection efficiencies would range from 28 to 333%, collection efficiencies cannot be greater than 100% and 28% is much lower than what is generally accepted when large amounts of breakthrough are not expected. This method was rejected and not incorporated into the final calculated values for atmospheric HTO concentration.

[20] The Weather Company, an IBM business, 1001 Summit Boulevard, Floor 20, Brookhaven, GA, USA 30319

The method 2 approach which placed hygrometers before and after the MS beds provide results that could be better justified. This process showed a decline of RH% from 71.2 to 11.2% (MS column half filled) to 4.0% (MS column full). This results in a collection efficiency of 94%. At the end of sampling period, the RH% in the front of the desiccant column read 24.3% before and 23.8% after the MS column, this implies that by the end of the sampling period the collection efficiencies could have dropped to as low as 2%. The fluctuations in collection efficiencies could be recorded during the sampling process using the method 2 approach and detail how efficient the water vapor was adsorbed as sampling progressed. This would better quantify and reduce the uncertainty in Δm.

The summarized experimental data found in Table 3.5 details the correlation between the sampling variables and method 1 collection efficiencies for the experimental CFA samples.

Table 3.5. Correlation between CFA water sampling variables with a hygrometer and associated collection efficiencies

Variable	Average	StDev	PCC between variable and collection efficiency
Collection Efficiency	7.30%	1.40×10^{-3}	NA
Temperature (ºC)	22.75	0.85	-0.68
RH%	29.76	11.26	0.42
MS Column Weight (g)	383.00	4.53	0.94
AH (g m^{-3})	5.95	2.03	0.38
Flow Rate (m^3 min^{-1})	2.23×10^{-3}	6.53×10^{-6}	-0.68

The experimental collection efficiencies remained consistent (7.30 ± 0.14%) when other variables such as, climate conditions, flow rates, and MS column sizes remained constant.

However, as previously described, these collection efficiencies do not include sample breakthrough and were rejected.

3.3 Data Analysis and Uncertainty Derivation

Variable W in the analysis of atmospheric HTO concentrations in equation 1.2 details the change in mass by the MS during the sampling period. The uncertainty was originally characterized by the IDEQ from the uncertainty of the balance (σ = 0.05g). (Ritter 2014). The study reviewed the average temperature and RH% during the sampling period. The atmospheric HTO concentrations and uncertainties were derived using equation 2.2. An example of the uncertainty derivation is provided in equation 3.1.

$$\sigma_{\Delta m} = \sqrt{(0.03)^2 + \left(\left(\frac{0.8}{20}\right) * 100\right)^2 + (0.04)^2 + \left(\frac{0.5}{77}\right)^2} = 0.09g \qquad \textbf{(3.1)}$$

Since the experimentally derived collection efficiencies were not used, predetermined collection efficiencies ranging from 100 to 40% were used to illustrate how incorporating collection efficiencies affect final atmospheric HTO concentrations. The atmospheric HTO concentrations were calculated using equation 2.3 to determine a new uncertainty for the mass gained during the sampling process. The average sampling parameters were used for this calculation. These average sampling values were obtained from the IDEQ's historical sampling data at each location from 2012 through 2014. The data shows that as collection efficiency for the MS decreases, the atmospheric HTO concentrations and associated uncertainty increases. Examples of the data are presented in Table 3.6. The changes to collection efficiency are portrayed in Figure 3.1.

Table 3.6 Identifying how concentrations and uncertainties are affected by integrating collection efficiencies into final atmospheric HTO concentrations

Variable Averages	Δm (g) (100%)	Δm (g) (90%)	Δm (g) (80%)	Δm (g) 50%)
Weight Gain (g)	77 ± 0.09	86 ± 0.09	96 ± 0.08	154 ± 0.07
Temperature (°C)	20 ± 0.08	20 ± 0.08	20 ± 0.08	20 ± 0.08
RH%	60 ± 4	60 ± 4	60 ± 4	60 ± 4
Column Size (g)	1432 ± 0.05	1432 ± 0.05	1432 ± 0.05	1432 ± 0.05
Corrected Volume (m^3)	16.61 ± 0.014	16.61 ± 0.014	16.61 ± 0.014	16.61 ± 0.014
LSC HTO Activity (pCi ml^{-1})	0.23 ± 0.05	0.23 ± 0.05	0.23 ± 0.05	0.23 ± 0.05
Atmospheric HTO (pCi ml^{-1})	1.07 ± 0.23	1.18 ± 0.26	1.33 ± 0.29	2.13 ± 0.46

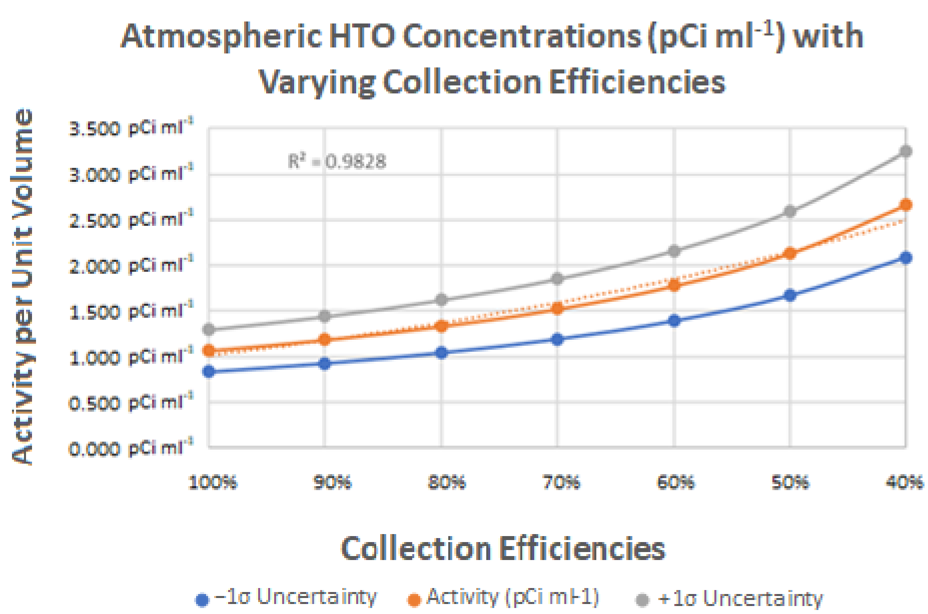

Figure 3.1 Reported atmospheric HTO at constant concentrations with varying collection efficiencies

Chapter 4: Conclusion and Recommendations

The IDEQ's frequent calibrations and pre-sampling equipment checks, along with the precision equipment and procedures used in the laboratories, create conditions in which the bulk of the remaining unaccounted-for uncertainty would lie in the performance of the MS. The IDEQ uses two desiccant columns in a series, with moisture indicating MS in the latter column, to optimize collection efficiencies and reduce uncertainty. This study reviewed 464 samples over the course of three years. There is no evidence suggesting that any sampling variables, other than those already controlled such as flow rate and MS desiccant column sizes, would affect or significantly impact measured HTO concentrations or collection efficiencies.

Collection efficiency of the MS could be derived by knowing exactly how much water mass is adsorbed and how much water could have been adsorbed. The data retrieved from the experimental data collection supported this idea that a collection efficiency could be derived using data-logging inline hygrometers. The amount of mass gained by the MS during the sampling duration would be compared to a collection efficiency which has been derived by the hygrometer's RH% readings before and after the MS column beds. However, calculating MS collection efficiencies with data from only one hygrometer would be insufficient.

4.1 Recommendations

At these extremely low environmental levels (three to four orders of magnitude lower than regulatory requirements) a relative error that may at times reach as high as 20% is still extremely small and may not be worth the cost of implementation; the additional resources needed to incorporate hygrometers into the sampling stations, procedures, and collecting and analyzing the additional data, could detract from any incentives to uncertainty reduction.

4.2 Results of the Hypothesis Testing

Concerning Atmospheric HTO Concentrations.

- 1a. The null hypothesis was rejected for the alternate hypothesis as implementing hygrometers into the sampling process line quantifies collection efficiencies.

Concerning the Relationship between MS Collection Efficiency and Temperature and Humidity.

- 2a. The null hypothesis failed to be rejected as there is no relationship (R^2 between -1.0 to -0.7 or 0.7 to 1.0) found when reviewing the IDEQ sampling data between MS collection efficiencies and Temperature.
- 2b. The null hypothesis failed to be rejected as there is no strong relationship (R^2 between -1.0 to -0.7 or 0.7 to 1.0) found when reviewing the IDEQ sampling data between MS collection efficiencies and Humidity.

Chapter 5: References

ANL. Argonne National Laboratory. Human Health Fact Sheet. Tritium (Hydrogen-3). 2001 Available at http://hpschapters.org/northcarolina/NSDS/tritium.pdf. Accessed January 17, 2019

Armarego WLF, Chai C. Purification of Laboratory Chemicals, 6th ed. Amsterdam: Butterworth-Heiemann; 2009.

Chen Y, Qui Y, Zhang G, Yu L, Mantri R. Developing Solid Oral Dosage Forms Pharmaceutical Theory and Practice. 2nd ed. Amsterdam. Elsevier, 2017

CNSC. Canadian Nuclear Safety Commission. Evaluation of Facilities Handling Tritium. Ottawa, Canada: INFO-0796; 2010.

CNSC. Canadian Nuclear Safety Commission. Investigation of the Environmental Fate of Tritium in the Atmosphere. Ottawa, Canada: INFO-0792; 2009.

Craig H, Devendra LA. The Production Rate of Natural Tritium. Scripps Institution of Oceanography. Tellus XIII (1961). Available at http://repository.ias.ac.in/19224/1/19224.pdf. Accessed on 4 December 2018

Currie LA. Limits for Qualitative Detection and Quantitative Determination Application to Radiochemistry. Analytical Chemistry (40): 586-593; 1968.

Deziel C. How to Convert SCFM to CFM. 2018. Sciencing.com. Available at https://sciencing.com/convert-scfm-cfm-6156309.html. Accessed June 7, 2019.

Eisenbud M, Gesell TF. Environmental Radioactivity, 4th ed. San Diego: Academic Press; 1997.

EPA. Environmental Protection Agency. The Public Health Service Act. Title XIV. Safety of Public Water Systems (Safe Drinking Water Act). 1974.

Farag HA, Ezzat MM, Amer H, Nashed AW. Natural Gas Dehydration by Desiccant Materials. Alexandria Engineering Journal (50): 431-439; 2011.

Garg DR, Ruthven DM. Theoretical prediction of Breakthrough Curves for Molecular Sieve Adsorption Columns – I Asymptotic Solutions. Chemical Engineering Science (28): 791-798; 1973.

HPS. Health Physics Society Radiation Terms. 950 Herndon Parkway, Suite 450 Herndon, VA 20170, 2011. Available at http://hps.org/publicinformation/radterms/radfact116.html. Accessed on 21 October 2017

HPS. Health Physics Society Tritium Fact Sheet. 950 Herndon Parkway, Suite 450 Herndon, VA 20170. Available at https://hps.org/documents/tritium_fact_sheet.pdf. Accessed June 14, 2019

Helfer F, Lemckert C, Zhang H. Influence of Bubble Plumes on Evaporation from Non-Stratified Waters. Journal of Hydrology (438): 84-96; 2012.

IAEA. International Atomic Energy Agency. Safe Handling of Tritium. Vienna, Austria: Technical Report Series No. 324; 1991.

IAEA. International Atomic Energy Agency. Environmental Isotopes in the Hydrological Cycle Principles and Applications. Volume II. Vienna, Austria. 2000.

ICRP. International Commission on Radiological Protection. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30 (Index). Ann. ICRP 8 (4). Pergamon Press. Maxwell House, Fairview Park. Elmsford, NY 10523, USA. 1982.

ICRP. International Commission on Radiological Protection. Individual Monitoring for Internal Exposure of Workers (Preface and Glossary Missing). ICRP Publication 78. Ann. ICRP 27 (3-4). Pergamon Press. Maxwell House, Fairview Park. Elmsford, NY 10523, USA. 1997.

IDEQ. Idaho Department of Environmental Quality. DEQ-INL Oversight Program Annual Report 2017. Available at https://www.deq.idaho.gov/media/60182161/inl-oversight-program-annual-report-2017.pdf. Accessed December 3, 2018.

ISO. International Organization for Standardization. ISO/IEC Guide 98-3:2008. Uncertainty of measurement Part 3: Guide to the expression of uncertainty in measurement (GUM:1995). Geneva: ISO; 2008

Kim SB, Baglan N, Davis PA. Current Understanding of Organically Bound Tritium (OBT) into the Environment. Journal of Environmental Radioactivity (126): 83-91; 2013.

Kouts H, Long J. Tritium Production in Nuclear Reactors. In “Tritium” (Moghissi AA, Carter MW, eds) 38-45. Messenger Graphics. Phoenix, Arizona. 1973.

Laerd Statistics. Pearson Product-Moment Correlation. Available at https://statistics.laerd.com/statistical-guides/pearson-correlation-coefficient-statistical-guide.php. Accessed June 16, 2019.

L'Annunziata MF. Handbook of Radioactivity Analysis. 3rd ed. Amsterdam: Academic Press. 2012.

Lawrence MG. The Relationship between Relative Humidity and the Dewpoint Temperature in Moist Air. American Meteorological Society (86): 225-234; 2005.

Lewis C. Atmospheric Moisture Sampler Volume Measurement Calibration. IDEQ Standard Operating Procedure. State of Idaho, Department of Environmental Quality. 2014

Lunt M. Sampling and Confidence Intervals. University of Manchester. Arthritis Research, UK Epidemiology Unit. 2018. Available at https://personalpages.manchester.ac.uk/staff/mark.lunt/stats/3_Sampling_and_CI/Slides.pdf. Accessed June 12, 2019.

Mander P. How to Convert Relative Humidity to Absolute Humidity. Carnotcycle. Available at https://carnotcycle.wordpress.com/2012/08/04/how-to-convert-relative-humidity-to-absolute-humid. Accessed July 22, 2017.

Mokhatab S, Poe WA, Mak JY. Handbook of Natural Gas Transmission and Processing. 3rd ed. Burlington Massachusetts. Gulf Professional Publishing. 2015.

Murphey CE. Tritium and Cycling in the Environment. Health Physics (65): 683-697; 1993

National Research Council. Radiological Assessment for Resettlement of Nongelap in the Republic of the Marshall Islands. Committee on Radiological Safety in the Marshall Islands. Washington DC. National Academies Press. 1994

NCRP. National Council on Radiation Protection and Measurements. Tritium in the Environment. Bethesda, MD: NCRP Report No. 062; 1979.

NRC. Nuclear Regulatory Commission. 10CFR20. Standards for Protection Against Radiation. 1995 Available at https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/. Accessed July 17, 2018.

NRC. Nuclear Regulatory Commission. Office of Public Affairs. Tritium Production. 2005. Available at http://www.nrc.gov/docs/ML032521359.pdf. Accessed December 9, 2018.

Ojovan MI, Lee WE. An Introduction to Nuclear Waste Immobilisation 2nd ed. London, England. Elsevier 2014.

Okada S, Momoshima N. Overview of Tritium: Characteristics, Sources, and Problems. Health Physics Society (65): 595-609; 1993.

Paulus LR, Walker DW, Thompson KC. A Comparison of Desiccant Materials used for Monitoring Atmospheric Tritium Concentrations in a Semi-Arid Climate. Health Physics Society (85): 348-356; 2003.

Radiological Society of North America Inc. Radiation Dose in X-ray and CT Exams. 2019. Available at https://www.radiologyinfo.org/en/pdf/safety-xray.pdf. Accessed June 4, 2019.

Ritter P. Atmospheric Tritium Sample Collection. IDEQ Standard Operating Procedure. State of Idaho, Department of Environmental Quality. 2014

Straume, T. Tritium Risk Assessment. Health Physics Society (65): 673-682; 1993

Teegarden BJ. Cosmic-ray Production of Deuterium and Tritium in the Earth’s Atmosphere. Journal of Geophysical Research (72): 4863-4868; 1967

Tetens VO. Über einige Meteotologische Begriffe, Zeitschrift für Geophysisik (6): 297-309; 1930.

Turner JE, Downing DJ, Bogard JS. Statistical Methods in Radiation Physics. Weinheim, Germany. Wiley-VCH. 2012.

UNSCEAR 1988. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources, Effects and Risks of Ionizing Radiation. New York: United Nations, 1988.

UNSCEAR 2016. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources, Effects and Risks of Ionizing Radiation. New York: United Nations, 2017.

VDI. The Association of German Engineers. Variable-area Flowmeters - Maximum Permissible Errors, G, of the System. VDI/VDE 3513 Page 2; 2014. Available at https://www.vdi.eu/guidelines/vdivde_3513_blatt_2-schwebekoerperdurchflussmesser_fehlergrenzen_g_des_geraets/. Accessed June 7, 2019

Zhang X, Luo Ju Tang C. Sensitivity Characteristic Analysis of Adsorbent-Mixed Carbon Nanotube Sensors for the Detection of SF6 Decomposition Products under PD Conditions. Sensors (13): 15209-15220; 2013. Available at https://www.researchgate.net/publication/258429045_Sensitivity_Characteristic_Analysis_of_Adsorbent-mixed_Carbon_Nanotube_Sensors_for_the_Detection_of_SF6_Decomposition_Products_under_PD_Conditions.

Appendix A – IDEQ Sampling Data from Microsoft Excel[21]

Table A1 – IDEQ HTO Atomic City 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH (g m^{-3})	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121ATR02	AC	12/29/11	03/01/12	63.00	3.31	1427.7	1501.6	73.9	65.57	112.71	42.3	2978.18	4180.70	1202.52	29.04
OP121ATR03	AC	03/01/12	03/29/12	27.96	4.23	1463.1	1498.2	35.1	67.27	52.18	26.6	4180.70	4616.31	435.61	10.52
OP122ATR02	AC	03/29/12	05/10/12	42.01	4.45	1499.6	1572.0	72.4	72.61	99.72	35.4	4616.31	5407.65	791.34	19.11
OP122ATR03	AC	05/10/12	06/13/12	34.07	5.81	1520.6	1609.6	89.0	66.26	134.33	41.9	5407.65	6224.13	816.48	19.72
OP122ATR04	AC	06/13/12	06/28/12	14.95	6.82	1460.8	1497.5	36.7	52.73	69.59	25.8	6224.13	6584.50	360.37	8.70
OP123ATR02	AC	06/28/12	07/19/12	21.02	9.39	1502.4	1585.9	83.5	63.51	131.48	47.6	6584.50	7079.00	494.50	11.94
OP123ATR02	AC	06/28/12	07/19/12	21.02	9.39	1502.4	1585.9	83.5	63.51	131.48	47.6	6584.50	7079.00	494.50	11.94
OP123ATR03	AC	07/19/12	08/16/12	27.99	8.59	1473.6	1563.0	89.4	54.78	163.20	38.7	7079.00	7749.94	670.94	16.20
OP123ATR04	AC	08/16/12	09/06/12	21.03	6.96	1514.3	1589.3	75.0	65.17	115.08	46.7	7749.94	8333.87	583.93	14.10
OP123ATR05	AC	09/06/12	09/27/12	21.03	6.08	1446.4	1502.2	55.8	64.88	86.01	31.4	8333.87	8833.43	499.56	12.07
OP124ATR02	AC	09/27/12	11/01/12	34.95	4.18	1496.4	1579.2	82.8	86.29	95.95	37.5	8833.43	9644.08	810.65	19.58
OP124ATR03	AC	11/01/12	12/13/12	42.01	4.07	1521.9	1616.5	94.6	93.45	101.23	42.0	9644.08	10522.40	878.32	21.21
OP131ATR02	AC	12/27/12	02/28/13	62.99	2.47	1416.0	1499.7	83.7	75.19	111.32	43.5	844.41	2435.97	1591.56	38.44
OP131ATR03	AC	02/28/13	03/28/13	28.03	3.44	1456.2	1497.4	41.2	82.65	49.85	38.9	2435.97	2947.70	511.73	12.36
OP132ATR02	AC	03/28/13	05/02/13	34.94	3.56	1470.5	1530.0	59.5	77.84	76.44	41.7	2947.70	3706.00	758.30	18.31
OP132ATR03	AC	05/02/13	05/30/13	28.01	5.90	1461.1	1532.3	71.2	71.41	99.71	46.9	3706.00	4302.80	596.80	14.41
OP132ATR04	AC	05/30/13	06/27/13	28.05	7.31	1463.5	1556.7	93.2	65.47	142.36	48.4	4302.80	4990.55	687.75	16.61
OP133ATR02	AC	06/27/13	07/15/13	17.98	8.92	1504.2	1575.2	71.0	72.56	97.85	42.3	4990.55	5377.93	387.38	9.36
OP133ATR03	AC	07/15/13	08/01/13	16.98	10.07	1467.6	1531.2	63.6	50.01	127.18	34.7	5377.93	5823.94	446.01	10.77
OP133ATR04	AC	08/01/13	08/29/13	27.99	7.77	1476.0	1579.8	103.8	66.51	156.06	54.0	5823.94	6533.25	709.31	17.13
OP133ATR05	AC	08/29/13	09/19/13	21.00	7.95	1430.3	1528.4	98.1	91.58	107.12	59.6	6533.25	7009.07	475.82	11.49
OP134ATR02	AC	09/26/13	10/31/13	35.01	4.38	1526.2	1616.5	90.3	85.38	105.76	45.7	7168.15	8020.90	852.75	20.60
OP134ATR03	AC	10/31/13	12/12/13	41.96	2.46	1561.8	1626.9	65.1	107.71	60.44	46.7	8020.90	8888.53	867.63	20.96
OP141ATR02	AC	01/02/14	04/03/14	91.00	3.56	1441.0	1514.8	73.8	40.27	183.26	39.2	9290.25	11108.20	1817.95	43.91
OP142ATR02	AC	04/03/14	05/08/14	34.99	4.02	1536.1	1596.6	60.5	74.35	81.38	66.8	1108.20	1823.07	714.87	17.27
OP142ATR03	AC	05/08/14	06/12/14	35.00	7.93	1551.8	1625.6	73.8	41.53	177.70	55.4	1823.07	2614.41	791.34	19.11
OP142ATR03	AC	05/08/14	06/12/14	35.00	7.93	1551.8	1625.6	73.8	41.53	177.70	55.4	1823.07	2614.41	791.34	19.11
OP142ATR04	AC	06/12/14	07/03/14	21.03	6.82	1489.2	1565.8	76.6	70.69	108.36	36.6	2614.41	3175.49	561.08	13.55
OP143ATR02	AC	07/03/14	08/21/14	48.99	9.26	1505.5	1619.9	114.4	34.24	334.07	48.3	3175.49	4449.51	1274.02	30.77
OP143ATR03	AC	08/21/14	10/02/14	42.01	6.82	1476.4	1565.6	89.2	37.52	237.73	63.4	4449.56	5680.53	1230.97	29.73
OP144ATR02	AC	10/02/14	10/30/14	28.00	5.09	1469.6	1543.1	73.5	82.42	89.18	35.6	5680.53	6299.27	618.74	14.94
OP144ATR02	AC	10/02/14	10/30/14	28.00	5.09	1469.6	1543.1	73.5	82.42	89.18	35.6	5680.53	6299.27	618.74	14.94
OP144ATR03	AC	10/30/14	12/31/14	61.90	3.37	1569.1	1663.9	94.8	81.05	116.97	65.1	6299.27	7524.97	1225.70	29.60

[21] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

Table A2 – IDEQ HTO Craters of the Moon 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121CTR02	CM	12/29/11	03/01/12	63.03	2.63	1333.2	1410.4	77.2	92.93	83.08	31.7	7899.41	9014.94	1115.53	26.94
OP121CTR03	CM	03/01/12	03/29/12	27.95	3.77	1394.0	1440.8	46.8	85.53	54.72	22.3	9014.94	9527.50	512.56	12.38
OP122CTR02	CM	03/29/12	05/03/12	35.07	3.69	1483.3	1566.0	82.7	90.41	91.47	40.7	9527.50	10402.92	875.42	21.14
OP122CTR02	CM	03/29/12	05/03/12	35.07	3.69	1483.3	1566.0	82.7	90.41	91.47	40.7	9527.50	10402.92	875.42	21.14
OP122CTR03	CM	05/03/12	06/07/12	35.00	4.67	1367.7	1450.1	82.4	86.06	95.75	34.6	402.92	1127.00	724.08	17.49
OP122CTR04	CM	06/07/12	06/28/12	20.98	4.99	1400.1	1458.5	58.4	71.61	81.55	36.7	1127.00	1704.14	577.14	13.94
OP122CTR04	CM	06/07/12	06/28/12	20.98	4.99	1400.1	1458.5	58.4	71.61	81.55	36.7	1127.00	1704.14	577.14	13.94
OP123CTR02	CM	06/28/12	07/19/12	21.02	6.94	1365.2	1454.4	89.2	81.84	108.99	40.4	1704.14	2258.76	554.62	13.40
OP123CTR03	CM	07/19/12	08/16/12	27.99	6.23	1384.3	1472.6	88.3	58.58	150.75	48.3	2258.76	3113.26	854.50	20.64
OP123CTR04	CM	08/16/12	09/06/12	21.02	5.51	1369.1	1457.5	88.4	70.65	125.13	36.2	3113.26	3915.23	801.97	19.37
OP123CTR05	CM	09/06/12	09/27/12	21.02	4.77	1440.2	1506.9	66.7	75.07	88.85	36.4	3915.23	4573.00	657.77	15.89
OP124CTR02	CM	09/27/12	11/08/12	41.96	3.69	1393.0	1468.2	75.2	65.43	114.94	34.4	4573.00	5673.00	1100.00	26.57
OP124CTR03	CM	11/08/12	12/14/12	36.13	3.50	1350.1	1415.1	65.0	70.66	91.99	31.7	5673.00	6601.19	928.19	22.42
OP131CTR02	CM	12/27/12	02/07/13	41.99	2.05	1447.6	1519.8	72.2	99.52	72.55	56.8	6955.77	8205.58	1249.81	30.19
OP131CTR03	CM	02/07/13	03/14/13	35.01	2.74	1491.0	1557.9	66.9	87.46	76.49	45.1	8205.58	9191.42	985.84	23.81
OP131CTR04	CM	03/14/13	03/28/13	14.03	2.96	1385.0	1418.2	33.2	99.74	33.29	21.6	9191.42	9588.56	397.14	9.59
OP132CTR02	CM	03/28/13	05/02/13	34.96	3.28	1346.6	1415.1	68.5	82.97	82.56	36.2	9588.56	10477.50	888.94	21.47
OP132CTR03	CM	05/02/13	05/30/13	28.01	4.85	1340.6	1417.7	77.1	80.19	96.15	40.2	477.50	1177.59	700.09	16.91
OP132CTR04	CM	05/30/13	06/27/13	28.04	5.81	1417.0	1510.3	93.3	75.51	123.56	54.7	1177.59	1928.61	751.02	18.14
OP133CTR02	CM	06/27/13	07/25/13	27.95	6.16	1350.8	1436.3	85.5	59.47	143.77	48.9	1928.61	2752.83	824.22	19.91
OP133CTR03	CM	07/25/13	08/15/13	21.03	5.94	1442.6	1509.8	67.2	60.33	111.38	52.6	2752.83	3415.00	662.17	15.99
OP133CTR04	CM	08/15/13	09/05/13	20.99	5.72	1429.9	1534.3	104.4	87.97	118.68	62.2	3415.00	4147.73	732.73	17.70
OP133CTR05	CM	09/05/13	09/26/13	21.01	4.87	1401.6	1492.9	91.3	113.57	80.39	61.4	4147.73	4730.69	582.96	14.08
OP134CTR02	CM	09/26/13	10/31/13	35.02	4.01	1438.5	1527.8	89.3	93.42	95.59	47.1	4730.69	5572.56	841.87	20.33
OP134CTR03	CM	10/31/13	12/12/13	41.96	2.84	1392.4	1484.0	91.6	88.37	103.66	45.8	5572.56	6861.49	1288.93	31.13
OP134CTR03	CM	10/31/13	12/12/13	41.96	2.84	1392.4	1484.0	91.6	88.37	103.66	45.8	5572.56	6861.49	1288.93	31.13
OP134CTR04	CM	12/12/13	01/02/14	20.97	2.24	1408.4	1457.0	48.6	111.09	43.75	29.5	6861.49	7551.23	689.74	16.66
OP141CTR02	CM	01/02/14	02/20/14	49.03	2.86	1382.9	1478.8	95.9	77.54	123.67	54.9	7551.23	9078.33	1527.10	36.88
OP141CTR03	CM	02/20/14	03/20/14	27.99	3.62	1354.7	1421.8	67.1	74.06	90.61	39.2	9078.33	9962.24	883.91	21.35
OP141CTR04	CM	03/20/14	04/03/14	13.99	3.51	1371.5	1409.8	38.3	85.83	44.62	21.7	9962.24	10411.20	448.96	10.84
OP142CTR02	CM	04/03/14	06/12/14	70.00	4.03	1403.0	1470.1	67.1	33.18	202.21	39.6	411.20	2183.12	1771.92	42.80
OP143CTR02	CM	07/03/14	07/31/14	28.00	6.67	1343.1	1441.1	98.0	61.17	160.20	48.2	2754.50	3602.70	848.20	20.49
OP143CTR03	CM	07/31/14	08/08/14	7.95	8.49	1478.7	1526.4	47.7	86.42	55.20	56.1	3602.70	3832.30	229.60	5.55
OP143CTR03	CM	07/31/14	08/08/14	7.95	8.49	1478.7	1526.4	47.7	86.42	55.20	56.1	3602.70	3832.30	229.60	5.55
OP143CTR04	CM	08/08/14	08/22/14	14.00	8.49	1422.0	1507.6	85.6	76.28	112.22	42.1	3832.30	4299.10	466.80	11.27
OP143CTR05	CM	08/22/14	09/04/14	13.05	8.49	1479.6	1546.5	66.9	62.17	107.60	34.9	4299.10	4746.68	447.58	10.81
OP143CTR06	CM	09/04/14	10/02/14	28.00	5.84	1428.9	1538.1	109.2	68.06	160.44	54.4	4746.80	5716.97	970.17	23.43
OP144CTR02	CM	10/02/14	11/13/14	42.00	3.95	1358.6	1423.5	64.9	39.16	165.72	34.2	5716.97	7198.55	1481.58	35.78
OP144CTR03	CM	11/13/14	12/31/14	47.88	3.30	1389.9	1440.5	50.6	36.88	137.20	34.9	7198.55	8666.75	1468.20	35.46

Table A3 – IDEQ HTO Experimental Field Station 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121ETR02	EFS	12/29/11	03/29/12	90.96	3.23	1481.9	1535.9	54.0	29.51	182.97	39.1	6970.02	8970.46	2000.44	48.32
OP121ETR02	EFS	12/29/11	03/29/12	90.96	3.23	1481.9	1535.9	54.0	29.51	182.97	39.1	6970.02	8970.46	2000.44	48.32
OP122ETR02	EFS	03/29/12	05/03/12	35.07	9.09	1408.2	1468.9	60.7	33.54	181.00	38.1	8970.46	9673.63	703.17	16.98
OP122ETR02	EFS	03/29/12	05/03/12	35.07	9.09	1408.2	1468.9	60.7	33.54	181.00	38.1	8970.46	9673.63	703.17	16.98
OP122ETR03	EFS	05/03/12	06/07/12	34.99	5.26	1394.1	1477.8	83.7	81.46	102.75	41.7	9673.63	10363.49	689.86	16.66
OP122ETR03	EFS	05/03/12	06/07/12	34.99	5.26	1394.1	1477.8	83.7	81.46	102.75	41.7	9673.63	10363.49	689.86	16.66
OP122ETR04	EFS	06/07/12	06/28/12	20.98	6.82	1433.7	1478.6	44.9	53.53	83.87	29.5	363.49	797.80	434.31	10.49
OP122ETR04	EFS	06/07/12	06/28/12	20.98	6.82	1433.7	1478.6	44.9	53.53	83.87	29.5	363.49	797.80	434.31	10.49
OP123ETR02	EFS	06/28/12	07/19/12	21.02	9.39	1420.7	1518.3	97.6	77.31	126.25	45.6	797.80	1272.61	474.81	11.47
OP123ETR03	EFS	07/19/12	08/16/12	27.99	8.45	1342.8	1399.2	56.4	28.07	200.94	36.7	1272.61	2112.37	839.76	20.28
OP123ETR03	EFS	07/19/12	08/16/12	27.99	8.45	1342.8	1399.2	56.4	28.07	200.94	36.7	1272.61	2112.37	839.76	20.28
OP123ETR04	EFS	08/16/12	09/06/12	21.02	7.51	1432.9	1529.7	96.8	64.86	149.24	32.4	2112.37	2814.15	701.78	16.95
OP123ETR05	EFS	09/06/12	09/27/12	21.03	6.08	1356.7	1436.0	79.3	72.71	109.06	43.7	2814.15	3447.63	633.48	15.30
OP123ETR05	EFS	09/06/12	09/27/12	21.03	6.08	1356.7	1436.0	79.3	72.71	109.06	43.7	2814.15	3447.63	633.48	15.30
OP124ETR02	EFS	09/27/12	10/26/12	28.96	4.18	1503.0	1579.4	76.4	84.81	90.09	33.9	3447.63	4208.74	761.11	18.38
OP124ETR03	EFS	10/26/12	11/21/12	25.99	4.44	1399.5	1480.7	81.2	88.90	91.34	31.8	4208.74	4935.20	726.46	17.55
OP124ETR03	EFS	10/26/12	11/21/12	25.99	4.44	1399.5	1480.7	81.2	88.90	91.34	31.8	4208.74	4935.20	726.46	17.55
OP124ETR03	EFS	10/26/12	11/21/12	25.99	4.44	1399.5	1480.7	81.2	88.90	91.34	31.8	4208.74	4935.20	726.46	17.55
OP124ETR04	EFS	11/21/12	12/27/12	36.03	3.11	1467.0	1538.3	71.3	113.03	63.08	31.7	4935.20	5651.48	716.28	17.30
OP124ETR04	EFS	11/21/12	12/27/12	36.03	3.11	1467.0	1538.3	71.3	113.03	63.08	31.7	4935.20	5651.48	716.28	17.30
OP131ETR02	EFS	12/27/12	03/14/13	76.99	2.47	1353.4	1439.6	86.2	86.69	99.44	48.1	5651.48	7073.21	1421.73	34.34
OP131ETR02	EFS	12/27/12	03/14/13	76.99	2.47	1353.4	1439.6	86.2	86.69	99.44	48.1	5651.48	7073.21	1421.73	34.34
OP132ETR02	EFS	03/28/13	05/09/13	41.98	3.56	1509.3	1585.4	76.1	87.39	87.08	41.7	7355.52	8219.35	863.83	20.86
OP132ETR02	EFS	03/28/13	05/09/13	41.98	3.56	1509.3	1585.4	76.1	87.39	87.08	41.7	7355.52	8219.35	863.83	20.86
OP132ETR03	EFS	05/09/13	06/04/13	25.99	5.79	1456.9	1519.2	62.3	73.44	84.84	51.0	8219.35	8736.79	517.44	12.50
OP132ETR03	EFS	05/09/13	06/04/13	25.99	5.79	1456.9	1519.2	62.3	73.44	84.84	51.0	8219.35	8736.79	517.44	12.50
OP132ETR04	EFS	06/04/13	06/27/13	23.03	7.31	1409.4	1468.2	58.8	60.17	97.72	35.0	8736.79	9208.86	472.07	11.40
OP132ETR04	EFS	06/04/13	06/27/13	23.03	7.31	1409.4	1468.2	58.8	60.17	97.72	35.0	8736.79	9208.86	472.07	11.40
OP133ETR02	EFS	06/27/13	07/22/13	25.02	10.07	1366.1	1455.2	89.1	53.81	165.59	43.0	9208.86	9789.56	580.70	14.03
OP133ETR02	EFS	06/27/13	07/22/13	25.02	10.07	1366.1	1455.2	89.1	53.81	165.59	43.0	9208.86	9789.56	580.70	14.03
OP133ETR03	EFS	07/22/13	08/22/13	30.93	7.77	1516.3	1598.6	82.3	48.33	170.28	45.6	9789.56	10563.50	773.94	18.69
OP133ETR03	EFS	07/22/13	08/22/13	30.93	7.77	1516.3	1598.6	82.3	48.33	170.28	45.6	9789.56	10563.50	773.94	18.69
OP133ETR04	EFS	08/22/13	09/12/13	20.95	7.86	1396.3	1502.7	106.4	88.47	120.27	38.9	563.50	1103.88	540.38	13.05
OP133ETR05	EFS	09/12/13	09/26/13	14.08	7.95	1379.0	1435.4	56.4	83.65	67.43	37.0	1103.88	1403.39	299.51	7.23
OP134ETR02	EFS	09/26/13	10/31/13	35.01	4.38	1422.0	1505.4	83.4	87.26	95.58	47.1	1403.39	2174.00	770.61	18.61
OP134ETR02	EFS	09/26/13	10/31/13	35.01	4.38	1422.0	1505.4	83.4	87.26	95.58	47.1	1403.39	2174.00	770.61	18.61
OP134ETR03	EFS	10/31/13	01/02/14	62.93	2.86	1403.5	1493.4	89.9	79.45	113.16	54.6	2174.00	3571.22	1397.22	33.75
OP141ETR02	EFS	01/02/14	03/12/14	69.00	3.11	1441.6	1542.6	101.0	76.86	131.41	53.2	3571.22	5063.44	1492.22	36.04
OP141ETR02	EFS	01/02/14	03/12/14	69.00	3.11	1441.6	1542.6	101.0	76.86	131.41	53.2	3571.22	5063.44	1492.22	36.04
OP141ETR03	EFS	03/12/14	04/03/14	22.00	3.60	1454.1	1484.8	30.7	64.43	47.65	27.6	5063.44	5530.88	467.44	11.29
OP141ETR03	EFS	03/12/14	04/03/14	22.00	3.60	1454.1	1484.8	30.7	64.43	47.65	27.6	5063.44	5530.88	467.44	11.29
OP142ETR02	EFS	04/03/14	05/08/14	35.00	4.02	1402.3	1481.7	79.4	85.69	92.66	33.7	5530.88	6344.90	814.02	19.66
OP142ETR02	EFS	04/03/14	05/08/14	35.00	4.02	1402.3	1481.7	79.4	85.69	92.66	33.7	5530.88	6344.90	814.02	19.66
OP142ETR03	EFS	05/08/14	06/12/14	35.00	5.45	1511.5	1589.9	78.4	64.38	121.78	46.0	6344.90	7134.01	789.11	19.06
OP142ETR03	EFS	05/08/14	06/12/14	35.00	5.45	1511.5	1589.9	78.4	64.38	121.78	46.0	6344.90	7134.01	789.11	19.06
OP142ETR04	EFS	06/12/14	07/03/14	21.02	6.82	1412.0	1492.0	80.0	75.51	105.94	32.7	7134.01	7682.60	548.59	13.25
OP143ETR02	EFS	07/03/14	08/07/14	35.00	9.04	1440.5	1557.2	116.7	62.31	187.28	45.8	7682.60	8414.22	731.62	17.67
OP143ETR02	EFS	07/03/14	08/07/14	35.00	9.04	1440.5	1557.2	116.7	62.31	187.28	45.8	7682.60	8414.22	731.62	17.67
OP143ETR03	EFS	08/07/14	08/22/14	14.94	9.47	1416.5	1514.2	97.7	101.52	96.24	49.4	8414.22	8773.10	358.88	8.67
OP143ETR03	EFS	08/07/14	08/22/14	14.94	9.47	1416.5	1514.2	97.7	101.52	96.24	49.4	8414.22	8773.10	358.88	8.67
OP143ETR04	EFS	08/22/14	09/11/14	20.01	8.15	1428.2	1509.6	81.4	77.80	104.62	35.2	8773.10	9226.45	453.35	10.95
OP143ETR04	EFS	08/22/14	09/11/14	20.01	8.15	1428.2	1509.6	81.4	77.80	104.62	35.2	8773.10	9226.45	453.35	10.95
OP143ETR05	EFS	09/11/14	10/02/14	21.05	6.82	1349.3	1413.5	64.2	88.21	72.78	49.3	9226.45	9603.30	376.85	9.10
OP143ETR05	EFS	09/11/14	10/02/14	21.05	6.82	1349.3	1413.5	64.2	88.21	72.78	49.3	9226.45	9603.30	376.85	9.10
OP144ETR02	EFS	10/02/14	10/30/14	28.00	5.09	1446.2	1535.4	89.2	85.41	104.44	52.0	9603.30	10327.89	724.59	17.50
OP144ETR02	EFS	10/02/14	10/30/14	28.00	5.09	1446.2	1535.4	89.2	85.41	104.44	52.0	9603.30	10327.89	724.59	17.50
OP144ETR03	EFS	10/30/14	12/11/14	41.97	3.37	1458.1	1529.5	71.4	87.17	81.90	40.7	327.89	1186.18	858.29	20.73
OP144ETR04	EFS	12/11/14	12/31/14	19.93	3.51	1471.9	1514.1	42.2	97.53	43.27	25.5	1186.18	1621.53	435.35	10.51

Table A4 – IDEQ HTO Fort Hall 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121NTR02	FH	12/29/11	02/21/12	53.91	3.03	1432.9	1522.8	89.9	95.17	94.46	41.2	7767.31	8868.23	1100.92	26.59
OP121NTR03	FH	02/21/12	03/29/12	37.17	3.56	1373.0	1440.7	67.7	87.42	77.44	40.8	8868.23	9636.42	768.19	18.55
OP122NTR02	FH	03/29/12	05/02/12	33.83	4.17	1415.1	1497.0	81.9	105.36	77.74	33.3	9636.42	10294.74	658.32	15.90
OP122NTR03	FH	05/02/12	05/24/12	22.07	4.28	1505.1	1565.4	60.3	95.05	63.44	40.0	294.74	818.20	523.46	12.64
OP122NTR04	FH	05/24/12	06/14/12	21.08	4.95	1485.6	1571.8	86.2	118.02	73.04	44.7	818.20	1339.29	521.09	12.59
OP122NTR05	FH	06/14/12	06/28/12	13.92	5.61	1512.2	1562.3	50.1	97.21	51.54	32.6	1339.34	1663.76	324.42	7.84
OP123NTR02	FH	06/28/12	07/26/12	28.04	7.45	1422.7	1502.7	80.0	58.80	136.06	42.0	1663.76	2308.70	644.94	15.58
OP123NTR03	FH	07/26/12	08/27/12	31.94	6.63	1443.0	1530.4	87.4	57.05	153.19	38.8	2308.70	3124.66	815.96	19.71
OP123NTR04	FH	08/27/12	09/27/12	31.09	5.36	1404.4	1510.1	105.7	82.34	128.37	32.9	3124.66	3970.44	845.78	20.43
OP123NTR04	FH	08/27/12	09/27/12	31.09	5.36	1404.4	1510.1	105.7	82.34	128.37	32.9	3124.66	3970.44	845.78	20.43
OP124NTR02	FH	09/27/12	10/26/12	28.95	3.84	1434.1	1514.6	80.5	112.98	71.25	36.9	3970.44	4625.68	655.24	15.83
OP124NTR03	FH	10/26/12	11/29/12	33.98	3.77	1390.5	1486.9	96.4	121.52	79.33	51.5	4625.68	5368.80	743.12	17.95
OP124NTR04	FH	11/29/12	12/27/12	28.05	3.50	1474.9	1537.7	62.8	111.73	56.21	40.7	5368.80	5935.94	567.14	13.70
OP131NTR02	FH	12/27/12	02/28/13	63.01	2.99	1434.1	1522.1	88.0	81.42	108.08	46.8	5935.94	7212.46	1276.52	30.83
OP131NTR03	FH	02/28/13	03/28/13	28.05	3.74	1423.3	1472.4	49.1	85.26	57.59	35.2	7212.46	7756.26	543.80	13.13
OP132NTR02	FH	03/28/13	05/09/13	41.93	3.88	1462.1	1549.1	87.0	96.97	89.71	37.4	7756.26	8572.82	816.56	19.72
OP132NTR03	FH	05/09/13	06/03/13	24.89	4.62	1395.8	1466.1	70.3	111.68	62.95	41.6	8572.82	9054.00	481.18	11.62
OP132NTR04	FH	06/03/13	06/27/13	24.17	5.56	1421.6	1514.2	92.6	109.39	84.65	47.2	9054.00	9591.66	537.66	12.99
OP133NTR02	FH	06/27/13	07/15/13	17.85	6.66	1449.5	1542.3	92.8	124.96	74.27	38.5	9591.66	9985.46	393.80	9.51
OP133NTR03	FH	07/15/13	08/01/13	17.09	6.66	1418.0	1492.9	74.9	111.67	67.07	35.0	9985.46	10341.12	355.66	8.59
OP133NTR04	FH	08/01/13	08/29/13	27.99	6.15	1464.6	1565.1	100.5	104.31	96.35	52.8	341.12	894.38	553.26	13.36
OP133NTR05	FH	08/29/13	09/19/13	20.99	5.21	1434.8	1542.4	107.6	179.52	59.94	61.7	894.38	1300.65	406.27	9.81
OP134NTR02	FH	09/26/13	11/06/13	40.79	3.80	1489.4	1580.9	91.5	95.76	95.55	40.1	1447.17	2335.19	888.02	21.45
OP134NTR02	FH	09/26/13	11/06/13	40.79	3.80	1489.4	1580.9	91.5	95.76	95.55	40.1	1447.17	2335.19	888.02	21.45
OP134NTR03	FH	11/06/13	01/02/14	57.16	2.86	1439.2	1512.1	72.9	83.95	86.84	55.3	2335.19	3407.47	1072.28	25.90
OP134NTR03	FH	11/06/13	01/02/14	57.16	2.86	1439.2	1512.1	72.9	83.95	86.84	55.3	2335.19	3407.47	1072.28	25.90
OP141NTR02	FH	01/02/14	02/20/14	49.00	3.10	1424.8	1503.9	79.1	97.73	80.94	56.2	3407.47	4329.49	922.02	22.27
OP141NTR03	FH	02/20/14	04/03/14	42.02	3.48	1540.0	1610.7	70.7	91.98	76.86	59.4	4329.49	5109.49	780.00	18.84
OP142NTR02	FH	04/03/14	05/08/14	34.97	3.69	1418.5	1509.1	90.6	110.86	81.72	33.4	5109.49	5891.60	782.11	18.89
OP142NTR03	FH	05/08/14	06/02/14	24.94	4.85	1419.4	1508.7	89.3	90.06	99.16	50.2	5891.60	6613.61	722.01	17.44
OP142NTR03	FH	05/08/14	06/02/14	24.94	4.85	1419.4	1508.7	89.3	90.06	99.16	50.2	5891.60	6613.61	722.01	17.44
OP142NTR04	FH	06/02/14	06/23/14	20.99	5.37	1435.1	1541.9	106.8	47.54	224.64	47.9	6613.61	8090.92	1477.31	35.68
OP142NTR05	FH	06/23/14	07/03/14	10.09	5.37	1436.5	1482.9	46.4	135.31	34.29	32.9	8090.92	8316.44	225.52	5.45
OP143NTR02	FH	07/03/14	07/21/14	17.87	6.37	1419.5	1514.3	94.8	124.89	75.91	34.7	8316.44	8737.27	420.83	10.16
OP143NTR03	FH	07/21/14	08/07/14	17.11	6.27	1471.0	1570.1	99.1	133.82	74.06	52.4	8737.27	9154.38	417.11	10.07
OP143NTR04	FH	08/07/14	08/29/14	22.21	6.16	1429.3	1532.2	102.9	134.41	76.55	57.5	9154.38	9593.26	438.88	10.60
OP143NTR05	FH	08/29/14	10/02/14	33.82	6.05	1439.0	1549.0	110.0	81.92	134.27	58.4	9593.26	10377.04	783.78	18.93
OP144NTR02	FH	10/02/14	10/30/14	27.98	4.18	1482.4	1569.5	87.1	125.71	69.29	61.5	377.04	962.40	585.36	14.14
OP144NTR03	FH	10/30/14	12/11/14	41.95	3.48	1497.1	1583.0	85.9	111.90	76.76	45.2	962.40	1741.39	778.99	18.81
OP144NTR04	FH	12/11/14	12/31/14	20.02	2.74	1479.9	1520.5	40.6	144.74	28.05	25.4	1741.39	2102.92	361.53	8.73

Table A5 – IDEQ HTO Howe 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH (g m^{-3})	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121HTR02	HW	12/29/11	03/01/12	63.03	2.33	1414.3	1506.8	92.5	101.41	91.21	54.8	3187.78	4570.21	1382.43	33.39
OP121HTR03	HW	03/01/12	03/29/12	28.15	3.30	1434.5	1488.9	54.4	90.84	59.89	33.2	4570.21	5211.10	640.89	15.48
OP122HTR02	HW	03/29/12	05/03/12	34.84	3.61	1423.3	1495.7	72.4	86.06	84.12	26.5	5211.13	6034.06	822.93	19.88
OP122HTR03	HW	05/03/12	05/31/12	28.02	4.60	1442.7	1498.5	55.8	80.95	68.93	42.1	6034.06	6563.28	529.22	12.78
OP122HTR04	HW	05/31/12	06/28/12	27.98	5.26	1440.3	1530.5	90.2	95.70	94.26	41.0	6563.28	7196.10	632.82	15.28
OP123HTR02	HW	06/28/12	07/19/12	21.03	5.44	1438.3	1534.8	96.5	134.12	71.95	40.8	7196.10	7663.18	467.08	11.28
OP123HTR03	HW	07/19/12	08/09/12	20.98	5.20	1378.4	1458.1	79.7	112.22	71.02	54.8	7663.18	8145.50	482.32	11.65
OP123HTR04	HW	08/09/12	08/28/12	19.08	4.96	1465.3	1547.1	81.8	114.64	71.35	51.5	8145.50	8653.52	508.02	12.27
OP123HTR04	HW	08/09/12	08/28/12	19.08	4.96	1465.3	1547.1	81.8	114.64	71.35	51.5	8145.50	8653.52	508.02	12.27
OP123HTR05	HW	08/28/12	09/27/12	29.96	4.27	1407.5	1472.8	65.3	92.41	70.66	37.8	8653.52	9237.93	584.41	14.11
OP124HTR02	HW	09/27/12	11/08/12	41.97	3.74	1480.7	1572.7	92.0	93.11	98.81	52.9	9237.93	10170.93	933.00	22.53
OP124HTR03	HW	11/08/12	12/17/12	39.23	2.69	1483.7	1555.7	72.0	128.48	56.04	30.9	170.93	906.61	735.68	17.77
OP131HTR02	HW	12/27/12	03/14/13	77.00	2.33	1407.5	1497.0	89.5	89.89	99.57	43.6	1101.60	2610.73	1509.13	36.45
OP132HTR02	HW	03/28/13	05/16/13	48.97	4.10	1479.6	1546.5	66.9	54.26	123.30	30.8	2873.79	3935.85	1062.06	25.65
OP132HTR03	HW	05/16/13	06/04/13	19.08	4.60	1549.3	1589.4	40.1	79.00	50.76	51.6	3935.85	4325.54	389.69	9.41
OP132HTR04	HW	06/04/13	06/27/13	22.94	5.26	1431.0	1496.8	65.8	81.11	81.13	39.2	4325.54	4870.20	544.66	13.15
OP133HTR02	HW	06/27/13	07/16/13	19.09	5.44	1451.3	1553.1	101.8	143.41	70.99	36.1	4870.20	5331.02	460.82	11.13
OP133HTR03	HW	07/16/13	08/08/13	22.92	5.20	1499.9	1587.3	87.4	119.33	73.24	54.2	5331.02	5828.44	497.42	12.01
OP133HTR04	HW	08/08/13	08/29/13	20.98	4.96	1441.9	1530.8	88.9	93.83	94.74	33.6	5828.44	6503.00	674.56	16.29
OP133HTR05	HW	08/29/13	09/19/13	21.00	4.27	1506.2	1610.1	103.9	333.04	31.20	57.7	6503.00	6761.02	258.02	6.23
OP134HTR02	HW	09/26/13	01/02/14	97.97	3.36	1444.6	1540.7	96.1	52.22	184.01	40.0	6911.31	8845.35	1934.04	46.71
OP141HTR02	HW	01/02/14	02/27/14	56.03	2.33	1557.8	1617.1	59.3	95.14	62.33	43.6	8845.35	9790.03	944.68	22.82
OP141HTR03	HW	02/27/14	04/03/14	34.97	3.30	1520.6	1565.5	44.9	76.43	58.75	49.4	9790.03	10418.70	628.67	15.18
OP142HTR02	HW	04/03/14	05/22/14	49.01	4.10	1429.9	1519.3	89.4	85.31	104.80	40.5	418.70	1321.38	902.68	21.80
OP142HTR02	HW	04/03/14	05/22/14	49.01	4.10	1429.9	1519.3	89.4	85.31	104.80	40.5	418.70	1321.38	902.68	21.80
OP142HTR03	HW	05/22/14	06/19/14	28.02	4.93	1470.6	1531.7	61.1	92.16	66.30	44.2	1321.38	1796.31	474.93	11.47
OP142HTR04	HW	06/19/14	07/03/14	14.00	5.26	1460.1	1503.3	43.2	125.22	34.50	29.7	1796.31	2027.93	231.62	5.59
OP143HTR02	HW	07/03/14	07/31/14	28.00	5.44	1432.9	1513.1	80.2	128.75	62.29	41.0	2027.93	2432.31	404.38	9.77
OP143HTR03	HW	07/31/14	08/21/14	21.01	4.96	1420.6	1516.5	95.9	161.43	59.41	54.4	2432.31	2855.28	422.97	10.22
OP143HTR03	HW	07/31/14	08/21/14	21.01	4.96	1420.6	1516.5	95.9	161.43	59.41	54.4	2432.31	2855.28	422.97	10.22
OP143HTR04	HW	08/21/14	09/11/14	20.96	4.61	1439.4	1515.7	76.3	136.45	55.92	45.6	2855.28	3283.64	428.36	10.35
OP143HTR05	HW	09/11/14	10/02/14	21.03	4.27	1523.3	1602.6	79.3	154.32	51.39	33.5	3283.64	3708.64	425.00	10.26
OP144HTR02	HW	10/02/14	11/06/14	34.99	3.74	1418.4	1514.3	95.9	120.89	79.33	39.4	3708.64	4457.70	749.06	18.09
OP144HTR03	HW	11/06/14	12/31/14	55.03	2.69	1458.6	1541.9	83.3	100.82	82.62	66.5	4457.70	5542.38	1084.68	26.20

Table A6 – IDEQ HTO Idaho Falls 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121ITR02	IF	12/29/11	02/09/12	42.05	2.97	1484.5	1566.3	81.8	102.01	80.19	39.0	3704.60	4658.04	953.44	23.03
OP121ITR03	IF	02/09/12	03/13/12	33.06	3.71	1491.6	1557.7	66.1	81.97	80.64	28.1	4658.04	5425.66	767.62	18.54
OP121ITR04	IF	03/13/12	03/29/12	15.99	4.05	1378.6	1426.7	48.1	114.87	41.87	29.0	5425.66	5790.79	365.13	8.82
OP121ITR04	IF	03/13/12	03/29/12	15.99	4.05	1378.6	1426.7	48.1	114.87	41.87	29.0	5425.66	5790.79	365.13	8.82
OP122ITR02	IF	03/29/12	05/02/12	34.09	4.32	1431.1	1510.2	79.1	95.76	82.60	35.9	5790.80	6466.03	675.23	16.31
OP122ITR03	IF	05/02/12	05/31/12	28.90	5.02	1455.3	1530.9	75.6	84.85	89.10	41.2	6466.03	7092.84	626.81	15.14
OP122ITR04	IF	05/31/12	06/28/12	27.98	6.02	1451.1	1544.4	93.3	77.81	119.91	47.8	7092.84	7796.25	703.41	16.99
OP123ITR02	IF	06/28/12	07/12/12	14.31	8.99	1485.0	1563.5	78.5	88.65	88.55	36.3	7796.25	8144.10	347.85	8.40
OP123ITR03	IF	07/12/12	07/26/12	13.70	8.99	1413.2	1494.9	81.7	83.06	98.37	44.5	8144.10	8530.51	386.41	9.33
OP123ITR04	IF	07/26/12	08/09/12	14.26	7.48	1509.2	1578.8	69.6	90.02	77.31	53.0	8530.51	8895.52	365.01	8.82
OP123ITR05	IF	08/09/12	08/23/12	13.76	7.48	1497.6	1571.9	74.3	98.74	75.25	30.8	8895.52	9250.77	355.25	8.58
OP123ITR06	IF	08/23/12	09/19/12	27.10	6.89	1430.8	1523.4	92.6	80.22	115.44	44.8	9250.77	9842.45	591.68	14.29
OP123ITR07	IF	09/19/12	09/27/12	7.88	6.30	1491.8	1550.8	59.0	110.27	53.50	31.4	9842.45	10142.37	299.92	7.24
OP124ITR02	IF	09/27/12	10/26/12	29.02	4.53	1474.3	1554.9	80.6	95.66	84.26	50.0	142.37	799.23	656.86	15.86
OP124ITR03	IF	10/26/12	11/15/12	19.99	4.60	1515.7	1576.3	60.6	92.75	65.33	39.9	799.23	1300.81	501.58	12.11
OP124ITR04	IF	11/15/12	12/13/12	28.00	3.99	1498.6	1580.0	81.4	108.40	75.09	48.0	1300.81	1965.46	664.65	16.05
OP131ITR02	IF	12/27/12	03/07/13	70.01	2.59	1522.6	1596.9	74.3	89.86	82.68	33.3	2154.83	3282.21	1127.38	27.23
OP131ITR03	IF	03/07/13	03/28/13	20.99	3.36	1430.9	1462.2	31.3	92.33	33.90	28.2	3282.20	3638.50	356.30	8.61
OP132ITR02	IF	03/28/13	05/02/13	35.01	3.70	1507.2	1572.1	64.9	84.69	76.63	44.0	3638.54	4369.96	731.42	17.67
OP132ITR03	IF	05/02/13	06/13/13	41.99	6.20	1512.5	1605.9	93.4	78.85	118.45	47.4	4369.96	5044.64	674.68	16.30
OP132ITR04	IF	06/13/13	06/27/13	14.02	6.75	1398.7	1456.1	57.4	86.30	66.51	34.9	5044.64	5392.63	347.99	8.40
OP133ITR02	IF	06/27/13	07/22/13	25.31	8.67	1486.9	1575.8	88.9	80.09	111.00	39.1	5392.63	5844.75	452.12	10.92
OP133ITR03	IF	07/22/13	08/15/13	23.70	8.21	1500.5	1581.7	81.2	80.05	101.44	73.5	5844.75	6281.09	436.34	10.54
OP133ITR04	IF	08/15/13	09/04/13	20.24	7.76	1532.7	1638.5	105.8	106.11	99.71	58.7	6281.09	6734.86	453.77	10.96
OP133ITR05	IF	09/04/13	09/19/13	14.76	7.93	1436.5	1549.3	112.8	111.89	100.81	53.8	6734.86	7183.82	448.96	10.84
OP133ITR06	IF	09/19/13	09/26/13	6.97	7.93	1447.5	1477.7	30.2	72.33	41.75	19.2	7183.82	7369.75	185.93	4.49
OP134ITR02	IF	09/26/13	10/31/13	35.06	4.56	1443.0	1539.7	96.7	94.57	102.26	55.4	7369.75	8161.66	791.91	19.13
OP134ITR02	IF	09/26/13	10/31/13	35.06	4.56	1443.0	1539.7	96.7	94.57	102.26	55.4	7369.75	8161.66	791.91	19.13
OP134ITR02	IF	09/26/13	10/31/13	35.06	4.56	1443.0	1539.7	96.7	94.57	102.26	55.4	7369.75	8161.66	791.91	19.13
OP134ITR03	IF	10/31/13	11/21/13	20.95	3.77	1486.1	1538.6	52.5	102.09	51.43	53.3	8161.66	8643.38	481.72	11.63
OP134ITR03	IF	10/31/13	11/21/13	20.95	3.77	1486.1	1538.6	52.5	102.09	51.43	53.3	8161.66	8643.38	481.72	11.63
OP134ITR04	IF	11/21/13	01/02/14	41.96	2.24	1414.4	1478.0	63.6	114.34	55.62	28.1	8643.38	9520.28	876.90	21.18
OP141ITR02	IF	01/02/14	02/27/14	56.03	3.18	1476.8	1567.5	90.7	92.69	97.85	45.0	9520.28	10606.95	1086.67	26.25
OP141ITR03	IF	02/27/14	04/03/14	34.96	3.58	1508.9	1568.7	59.8	90.96	65.74	31.5	606.95	1255.47	648.52	15.66
OP142ITR02	IF	04/03/14	05/22/14	49.01	4.61	1474.0	1552.3	78.3	78.26	100.05	45.3	1255.47	2021.87	766.40	18.51
OP142ITR03	IF	05/22/14	06/25/14	34.24	6.27	1527.8	1604.6	76.8	67.97	113.00	33.4	2021.87	2658.30	636.43	15.37
OP142ITR04	IF	06/25/14	07/03/14	7.78	6.27	1471.2	1502.8	31.6	105.68	29.90	20.5	2658.30	2826.72	168.42	4.07
OP143ITR02	IF	07/03/14	07/21/14	18.28	8.35	1415.0	1515.8	100.8	96.89	104.04	41.4	2826.72	3266.73	440.01	10.63
OP143ITR02	IF	07/03/14	07/21/14	18.28	8.35	1415.0	1515.8	100.8	96.89	104.04	41.4	2826.72	3266.73	440.01	10.63
OP143ITR03	IF	07/21/14	08/07/14	16.74	8.90	1529.5	1625.4	95.9	84.60	113.36	67.9	3266.73	3716.55	449.82	10.86
OP143ITR04	IF	08/07/14	08/22/14	15.20	9.46	1459.3	1555.2	95.9	96.09	99.80	58.1	3716.55	4089.10	372.55	9.00
OP143ITR05	IF	08/22/14	09/18/14	27.06	8.27	1446.6	1532.0	85.4	68.16	125.29	44.0	4089.10	4624.10	535.00	12.92
OP143ITR06	IF	09/18/14	10/02/14	13.73	7.08	1426.3	1486.1	59.8	111.94	53.42	43.8	4624.10	4890.57	266.47	6.44
OP144ITR02	IF	10/02/14	10/30/14	28.01	5.28	1508.4	1598.4	90.0	84.15	106.95	42.0	4890.57	5605.89	715.32	17.28
OP144ITR03	IF	10/30/14	12/11/14	42.00	3.50	1460.7	1544.3	83.6	88.61	94.34	39.3	5605.89	6557.80	951.91	22.99
OP144ITR04	IF	12/11/14	12/31/14	20.18	3.66	1499.2	1544.4	45.2	90.62	49.88	28.7	6557.80	7039.05	481.25	11.62

Table A7 – IDEQ HTO Monteview 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121MTR02	ML	12/29/11	02/09/12	42.03	2.19	1400.8	1476.4	75.6	110.01	68.72	41.6	2343.67	3451.83	1108.16	26.76
OP121MTR03	ML	02/09/12	03/13/12	33.05	2.46	1499.6	1563.3	63.7	109.10	58.39	34.0	3451.83	4290.00	838.17	20.24
OP121MTR04	ML	03/13/12	03/29/12	16.01	3.30	1379.2	1425.0	45.8	145.22	31.54	30.1	4290.00	4627.51	337.51	8.15
OP122MTR02	ML	03/29/12	04/26/12	27.95	3.61	1470.4	1550.7	80.3	101.82	78.86	43.5	4627.60	5399.07	771.47	18.63
OP122MTR03	ML	04/26/12	05/23/12	27.24	4.60	1406.9	1495.1	88.2	87.71	100.56	53.6	5399.07	6171.11	772.04	18.65
OP122MTR04	ML	05/23/12	06/13/12	20.80	4.93	1500.8	1582.1	81.3	122.58	66.32	43.9	6171.11	6646.21	475.10	11.47
OP122MTR05	ML	06/13/12	06/28/12	14.96	5.26	1455.1	1517.2	62.1	101.29	61.31	30.4	6646.21	7057.84	411.63	9.94
OP123MTR02	ML	06/28/12	07/12/12	14.31	5.44	1421.9	1508.8	86.9	151.48	57.37	32.1	7057.84	7430.25	372.41	8.99
OP123MTR03	ML	07/12/12	07/26/12	13.73	5.44	1500.4	1589.7	89.3	156.69	56.99	53.0	7430.25	7800.22	369.97	8.94
OP123MTR03	ML	07/12/12	07/26/12	13.73	5.44	1500.4	1589.7	89.3	156.69	56.99	53.0	7430.25	7800.22	369.97	8.94
OP123MTR04	ML	07/26/12	08/09/12	14.24	5.20	1505.8	1585.5	79.7	136.60	58.35	39.7	7800.22	8196.46	396.24	9.57
OP123MTR05	ML	08/09/12	08/23/12	13.76	4.96	1403.7	1503.7	100.0	150.12	66.61	50.8	8196.46	8670.75	474.29	11.46
OP123MTR06	ML	08/23/12	09/13/12	20.99	4.61	1459.8	1536.6	76.8	141.20	54.39	47.0	8670.75	9087.42	416.67	10.06
OP123MTR07	ML	09/13/12	09/27/12	14.00	4.27	1504.3	1546.0	41.7	135.37	30.80	29.9	9087.42	9342.18	254.76	6.15
OP124MTR02	ML	09/27/12	11/08/12	41.99	3.74	1497.1	1579.0	81.9	109.82	74.58	36.4	9342.18	10046.37	704.19	17.01
OP124MTR03	ML	11/08/12	12/13/12	35.02	3.07	1433.5	1510.5	77.0	128.14	60.09	43.3	46.37	737.61	691.24	16.70
OP131MTR02	ML	12/27/12	03/14/13	77.00	2.41	1494.5	1583.6	89.1	90.75	98.18	38.7	984.78	2423.40	1438.62	34.75
OP132MTR02	ML	03/28/13	05/09/13	42.01	3.61	1448.7	1534.0	85.3	88.16	96.75	48.8	2708.30	3654.76	946.46	22.86
OP132MTR03	ML	05/09/13	05/23/13	13.96	4.60	1457.5	1502.1	44.6	122.99	36.26	37.7	3654.76	3933.16	278.40	6.72
OP132MTR04	ML	05/23/13	06/18/13	26.17	4.93	1506.7	1599.2	92.5	101.21	91.39	55.1	3933.16	4587.82	654.66	15.81
OP132MTR05	ML	06/18/13	06/27/13	8.84	4.93	1419.7	1464.9	45.2	136.99	33.00	32.0	4587.82	4824.18	236.36	5.71
OP133MTR02	ML	06/27/13	07/15/13	18.23	5.44	1509.2	1617.7	108.5	147.81	73.40	55.9	4824.18	5300.69	476.51	11.51
OP133MTR02	ML	06/27/13	07/15/13	18.23	5.44	1509.2	1617.7	108.5	147.81	73.40	55.9	4824.18	5300.69	476.51	11.51
OP133MTR03	ML	07/15/13	07/29/13	14.01	5.44	1463.6	1530.7	67.1	147.43	45.51	42.9	5300.69	5596.15	295.46	7.14
OP133MTR04	ML	07/29/13	08/15/13	16.77	4.96	1378.6	1482.6	104.0	131.63	79.01	48.1	5596.15	6158.70	562.55	13.59
OP133MTR05	ML	08/15/13	08/29/13	13.99	4.96	1473.6	1575.8	102.2	164.34	62.19	48.4	6158.70	6601.47	442.77	10.69
OP133MTR06	ML	08/29/13	09/12/13	13.95	4.27	1456.7	1561.1	104.4	209.94	49.73	46.7	6601.47	7012.75	411.28	9.93
OP133MTR07	ML	09/12/13	09/26/13	14.03	4.27	1472.0	1554.2	82.2	170.82	48.12	48.5	7012.75	7410.73	397.98	9.61
OP134MTR02	ML	09/26/13	10/31/13	35.05	3.74	1515.0	1597.9	82.9	111.31	74.48	39.2	7410.73	8114.00	703.27	16.99
OP134MTR03	ML	10/31/13	11/27/13	26.95	3.07	1525.4	1581.8	56.4	95.38	59.13	42.5	8114.00	8794.23	680.23	16.43
OP134MTR04	ML	11/27/13	01/02/14	35.96	2.31	1529.0	1578.3	49.3	96.40	51.14	27.2	8794.23	9576.07	781.84	18.88
OP141MTR02	ML	01/02/14	02/27/14	56.04	2.33	1461.5	1539.4	77.9	108.94	71.51	36.2	9576.07	10659.91	1083.84	26.18
OP141MTR03	ML	02/27/14	04/03/14	34.96	3.30	1492.7	1556.0	63.3	95.80	66.08	48.0	659.91	1367.02	707.11	17.08
OP142MTR02	ML	04/03/14	05/08/14	35.02	3.61	1436.7	1516.7	80.0	104.38	76.64	44.6	1367.02	2116.78	749.76	18.11
OP142MTR03	ML	05/08/14	06/05/14	27.98	4.60	1448.0	1528.2	80.2	103.37	77.58	56.0	2116.78	2712.39	595.61	14.39
OP142MTR04	ML	06/05/14	07/03/14	28.02	5.26	1448.8	1544.7	95.9	120.86	79.35	56.2	2712.39	3245.10	532.71	12.87
OP143MTR02	ML	07/03/14	07/21/14	18.21	5.44	1483.7	1571.8	88.1	156.60	56.26	54.6	3245.10	3610.32	365.22	8.82
OP143MTR03	ML	07/21/14	08/07/14	16.80	5.20	1433.4	1535.6	102.2	143.79	71.08	49.6	3610.32	4093.03	482.71	11.66
OP143MTR04	ML	08/07/14	08/22/14	15.14	4.96	1485.2	1589.7	104.5	180.10	58.02	42.2	4093.03	4506.15	413.12	9.98
OP143MTR04	ML	08/07/14	08/22/14	15.14	4.96	1485.2	1589.7	104.5	180.10	58.02	42.2	4093.03	4506.15	413.12	9.98
OP143MTR05	ML	08/22/14	09/04/14	12.87	4.61	1464.4	1537.7	73.3	151.71	48.31	36.6	4506.15	4876.26	370.11	8.94
OP143MTR06	ML	09/04/14	09/25/14	20.99	4.27	1514.4	1622.4	108.0	144.06	74.97	42.9	4876.26	5496.29	620.03	14.98
OP143MTR07	ML	09/25/14	10/02/14	6.99	4.27	1445.2	1493.3	48.1	180.14	26.70	33.5	5496.29	5717.12	220.83	5.33
OP144MTR02	ML	10/02/14	10/30/14	28.00	3.74	1523.6	1607.8	84.2	114.16	73.76	39.3	5717.12	6413.55	696.43	16.82
OP144MTR02	ML	10/02/14	10/30/14	28.00	3.74	1523.6	1607.8	84.2	114.16	73.76	39.3	5717.12	6413.55	696.43	16.82
OP144MTR03	ML	10/30/14	12/04/14	35.00	3.07	1546.9	1607.4	60.5	83.73	72.25	46.7	6413.55	7244.71	831.16	20.07
OP144MTR04	ML	12/04/14	12/31/14	27.11	2.31	1416.9	1472.9	56.0	140.87	39.75	35.2	7244.71	7852.45	607.74	14.68

Table A8 – IDEQ HTO Mud Lake 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121VTR02	MV	12/29/11	02/09/12	42.02	2.19	1429.2	1495.0	65.8	111.57	58.98	38.9	8903.65	9854.70	951.05	22.97
OP121VTR03	MV	02/09/12	03/13/12	33.05	2.46	1408.1	1445.1	37.0	101.47	36.46	41.2	9854.70	10378.16	523.46	12.64
OP121VTR04	MV	03/13/12	03/29/12	16.08	3.30	1414.7	1448.7	34.0	118.76	28.63	28.0	378.16	684.54	306.38	7.40
OP122VTR02	MV	03/29/12	05/03/12	34.87	3.61	1430.3	1512.2	81.9	102.33	80.04	30.4	684.65	1467.62	782.97	18.91
OP122VTR03	MV	05/03/12	05/31/12	28.02	4.60	1477.1	1551.5	74.4	95.07	78.26	41.0	1467.62	2068.43	600.81	14.51
OP122VTR04	MV	05/31/12	06/28/12	27.98	5.26	1427.9	1526.4	98.5	101.51	97.04	37.9	2068.43	2719.91	651.48	15.73
OP123VTR02	MV	06/28/12	07/12/12	14.31	5.44	1417.0	1499.0	82.0	156.45	52.41	34.5	2719.91	3060.15	340.24	8.22
OP123VTR03	MV	07/12/12	07/26/12	13.74	5.44	1496.6	1582.0	85.4	176.04	48.51	39.2	3060.15	3375.08	314.93	7.61
OP123VTR04	MV	07/26/12	08/09/12	14.23	5.20	1484.3	1558.8	74.5	138.96	53.61	38.8	3375.08	3739.17	364.09	8.79
OP123VTR05	MV	08/09/12	08/28/12	18.80	4.96	1423.9	1533.9	110.0	136.48	80.60	42.7	3739.17	4313.03	573.86	13.86
OP123VTR06	MV	08/28/12	09/19/12	22.04	4.27	1414.8	1513.0	98.2	131.15	74.88	50.3	4313.03	4932.30	619.27	14.96
OP123VTR07	MV	09/19/12	09/27/12	7.91	4.27	1396.1	1463.7	67.6	160.01	42.25	35.4	4932.30	5281.71	349.41	8.44
OP124VTR02	MV	09/27/12	11/08/12	41.98	4.01	1422.7	1508.7	86.0	84.79	101.42	48.7	5281.71	6174.91	893.20	21.57
OP124VTR03	MV	11/08/12	12/27/12	49.02	2.69	1482.3	1555.1	72.8	101.34	71.84	41.8	6174.91	7118.00	943.09	22.78
OP131VTR02	MV	12/27/12	03/28/13	91.02	2.45	1394.2	1478.3	84.1	73.64	114.20	39.3	7118.00	8764.09	1646.09	39.76
OP132VTR02	MV	03/28/13	05/23/13	55.97	4.10	1462.1	1549.1	87.0	69.37	125.42	37.4	8764.09	9844.35	1080.26	26.09
OP132VTR03	MV	05/23/13	06/18/13	26.17	4.93	1478.9	1547.2	68.3	90.34	75.60	45.5	9844.35	10385.89	541.54	13.08
OP132VTR04	MV	06/18/13	06/27/13	8.85	5.26	1464.6	1494.6	30.0	101.75	29.49	23.6	385.89	583.85	197.96	4.78
OP133VTR02	MV	06/27/13	07/16/13	19.16	5.44	1440.3	1540.9	100.6	149.00	67.52	45.9	583.85	1022.14	438.29	10.59
OP133VTR03	MV	07/16/13	08/01/13	15.85	5.44	1409.4	1500.2	90.8	153.30	59.23	40.5	1022.14	1406.65	384.51	9.29
OP133VTR04	MV	08/01/13	08/22/13	20.98	4.96	1497.5	1587.8	90.3	125.53	71.93	52.1	1406.65	1918.80	512.15	12.37
OP133VTR05	MV	08/22/13	09/12/13	20.96	4.61	1475.1	1594.3	119.2	186.59	63.88	52.7	1918.80	2408.17	489.37	11.82
OP133VTR05	MV	08/22/13	09/12/13	20.96	4.61	1475.1	1594.3	119.2	186.59	63.88	52.7	1918.80	2408.17	489.37	11.82
OP133VTR06	MV	09/12/13	09/26/13	14.03	4.27	1444.9	1513.8	68.9	173.59	39.69	43.2	2408.17	2736.43	328.26	7.93
OP134VTR02	MV	09/26/13	10/31/13	35.04	3.74	1417.7	1513.3	95.6	107.32	89.08	35.8	2736.43	3577.55	841.12	20.32
OP134VTR03	MV	10/31/13	01/02/14	62.91	2.69	1420.6	1514.9	94.3	92.64	101.79	48.9	3577.55	4913.89	1336.34	32.28
OP141VTR02	MV	01/02/14	02/27/14	56.03	2.33	1437.8	1515.4	77.6	104.38	74.35	42.0	4913.89	6040.73	1126.84	27.22
OP141VTR03	MV	02/27/14	04/03/14	34.96	3.30	1498.0	1544.4	46.4	71.96	64.48	47.9	6040.73	6730.79	690.06	16.67
OP142VTR02	MV	04/03/14	05/08/14	35.02	3.61	1475.7	1557.3	81.6	97.40	83.78	37.4	6730.79	7550.38	819.59	19.80
OP142VTR03	MV	05/08/14	06/05/14	27.99	4.60	1521.7	1600.0	78.3	99.38	78.79	46.5	7550.38	8155.27	604.89	14.61
OP142VTR04	MV	06/05/14	07/03/14	28.03	5.26	1471.8	1570.8	99.0	113.27	87.40	53.8	8155.27	8742.08	586.81	14.17
OP143VTR02	MV	07/03/14	07/21/14	18.17	5.44	1456.3	1545.5	89.2	160.96	55.42	49.4	8742.08	9101.84	359.76	8.69
OP143VTR02	MV	07/03/14	07/21/14	18.17	5.44	1456.3	1545.5	89.2	160.96	55.42	49.4	8742.08	9101.84	359.76	8.69
OP143VTR03	MV	07/21/14	08/08/14	17.92	5.20	1540.6	1618.1	77.5	144.63	53.58	47.1	9101.84	9465.75	363.91	8.79
OP143VTR04	MV	08/08/14	08/22/14	14.00	4.96	1414.6	1505.9	91.3	173.36	52.66	42.4	9465.75	9840.71	374.96	9.06
OP143VTR05	MV	08/22/14	09/11/14	19.86	4.61	1510.0	1591.6	81.6	141.53	57.66	39.9	9840.71	10282.39	441.68	10.67
OP143VTR06	MV	09/11/14	10/02/14	21.02	4.27	1456.1	1563.5	107.4	158.23	67.88	39.7	282.39	843.77	561.38	13.56
OP144VTR02	MV	10/02/14	11/06/14	34.99	3.74	1467.6	1554.3	86.7	128.72	67.36	61.1	843.77	1479.77	636.00	15.36
OP144VTR03	MV	11/06/14	12/31/14	55.01	2.69	1497.3	1587.0	89.7	93.26	96.18	58.6	1479.77	2742.48	1262.71	30.50

Table A9 – IDEQ HTO Rest Area 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121RTR02	RA	12/29/11	02/09/12	41.99	2.86	1462.9	1550.3	87.4	81.67	107.01	37.1	4580.85	5902.19	1321.34	31.91
OP121RTR02	RA	12/29/11	02/09/12	41.99	2.86	1462.9	1550.3	87.4	81.67	107.01	37.1	4580.85	5902.19	1321.34	31.91
OP121RTR03	RA	02/09/12	03/13/12	33.08	3.37	1425.8	1495.1	69.3	73.46	94.34	44.6	5902.19	6890.76	988.57	23.88
OP121RTR04	RA	03/13/12	03/29/12	15.90	4.23	1378.2	1426.8	48.6	100.28	48.46	27.7	6890.76	7295.36	404.60	9.77
OP122RTR02	RA	03/29/12	05/03/12	35.07	9.09	1435.4	1519.5	84.1	38.50	218.46	41.3	7295.36	8144.08	848.72	20.50
OP122RTR03	RA	05/03/12	05/31/12	27.99	5.26	1455.4	1523.7	68.3	67.06	101.85	43.5	8144.08	8827.89	683.81	16.52
OP122RTR03	RA	05/03/12	05/31/12	27.99	5.26	1455.4	1523.7	68.3	67.06	101.85	43.5	8144.08	8827.89	683.81	16.52
OP122RTR04	RA	05/31/12	06/28/12	27.99	6.82	1508.0	1583.5	75.5	58.38	129.33	39.7	8827.89	9497.59	669.70	16.17
OP122RTR04	RA	05/31/12	06/28/12	27.99	6.82	1508.0	1583.5	75.5	58.38	129.33	39.7	8827.89	9497.59	669.70	16.17
OP123RTR02	RA	06/28/12	07/19/12	21.02	9.39	1511.7	1589.2	77.5	58.79	131.83	40.2	9497.59	9993.40	495.81	11.98
OP123RTR02	RA	06/28/12	07/19/12	21.02	9.39	1511.7	1589.2	77.5	58.79	131.83	40.2	9497.59	9993.40	495.81	11.98
OP123RTR03	RA	07/19/12	08/16/12	27.99	8.45	1451.8	1534.5	82.7	48.29	171.27	37.1	9993.40	10709.19	715.79	17.29
OP123RTR04	RA	08/16/12	09/13/12	28.00	6.80	1422.6	1500.9	78.3	53.24	147.08	40.2	709.19	1473.04	763.85	18.45
OP123RTR04	RA	08/16/12	09/13/12	28.00	6.80	1422.6	1500.9	78.3	53.24	147.08	40.2	709.19	1473.04	763.85	18.45
OP123RTR05	RA	09/13/12	09/27/12	14.04	6.08	1443.5	1481.1	37.6	59.29	63.42	27.8	1473.04	1841.38	368.34	8.90
OP124RTR02	RA	09/27/12	11/15/12	48.97	4.68	1423.4	1509.3	85.9	80.71	106.43	46.3	1841.38	2644.50	803.12	19.40
OP124RTR02	RA	09/27/12	11/15/12	48.97	4.68	1423.4	1509.3	85.9	80.71	106.43	46.3	1841.38	2644.50	803.12	19.40
OP124RTR03	RA	11/15/12	12/14/12	28.92	3.77	1494.6	1563.2	68.6	96.56	71.04	31.4	2644.50	3309.97	665.47	16.07
OP124RTR03	RA	11/15/12	12/14/12	28.92	3.77	1494.6	1563.2	68.6	96.56	71.04	31.4	2644.50	3309.97	665.47	16.07
OP131RTR02	RA	12/27/12	02/21/13	55.99	2.47	1455.3	1525.9	70.6	77.84	90.70	55.8	3600.50	4897.24	1296.74	31.32
OP131RTR02	RA	12/27/12	02/21/13	55.99	2.47	1455.3	1525.9	70.6	77.84	90.70	55.8	3600.50	4897.24	1296.74	31.32
OP131RTR03	RA	02/21/13	03/28/13	35.03	3.77	1444.2	1502.2	58.0	70.01	82.84	47.0	4897.24	5673.23	775.99	18.74
OP132RTR02	RA	03/28/13	05/02/13	34.95	3.56	1530.5	1590.9	60.4	62.74	96.27	34.3	5673.23	6628.21	954.98	23.07
OP132RTR03	RA	05/02/13	05/30/13	28.01	5.79	1457.4	1535.4	78.0	60.78	128.32	45.5	6628.21	7410.88	782.67	18.90
OP132RTR04	RA	05/30/13	06/27/13	28.04	7.31	1520.5	1608.5	88.0	52.87	166.46	50.1	7410.88	8215.03	804.15	19.42
OP132RTR04	RA	05/30/13	06/27/13	28.04	7.31	1520.5	1608.5	88.0	52.87	166.46	50.1	7410.88	8215.03	804.15	19.42
OP133RTR02	RA	06/27/13	07/15/13	18.04	10.07	1430.9	1512.9	82.0	63.66	128.81	42.9	8215.03	8666.76	451.73	10.91
OP133RTR03	RA	07/15/13	08/01/13	16.93	10.07	1492.7	1565.9	73.2	47.41	154.41	37.2	8666.76	9208.25	541.49	13.08
OP133RTR03	RA	07/15/13	08/01/13	16.93	10.07	1492.7	1565.9	73.2	47.41	154.41	37.2	8666.76	9208.25	541.49	13.08
OP133RTR04	RA	08/01/13	08/29/13	27.99	7.77	1439.7	1552.2	112.5	62.76	179.25	45.0	9208.25	10022.94	814.69	19.68
OP133RTR05	RA	08/29/13	09/19/13	21.00	7.95	1488.2	1602.9	114.7	90.04	127.39	63.9	22.94	588.81	565.87	13.67
OP133RTR05	RA	08/29/13	09/19/13	21.00	7.95	1488.2	1602.9	114.7	90.04	127.39	63.9	22.94	588.81	565.87	13.67
OP134RTR02	RA	09/26/13	10/31/13	35.01	4.38	1466.8	1555.4	88.6	75.25	117.74	51.0	773.21	1722.54	949.33	22.93
OP134RTR02	RA	09/26/13	10/31/13	35.01	4.38	1466.8	1555.4	88.6	75.25	117.74	51.0	773.21	1722.54	949.33	22.93
OP134RTR02	RA	09/26/13	10/31/13	35.01	4.38	1466.8	1555.4	88.6	75.25	117.74	51.0	773.21	1722.54	949.33	22.93
OP134RTR03	RA	10/31/13	12/05/13	34.96	3.49	1540.9	1604.9	64.0	71.14	89.97	46.8	1722.54	2632.90	910.36	21.99
OP134RTR04	RA	12/05/13	01/02/14	27.97	2.06	1447.6	1480.5	32.9	77.74	42.32	30.5	2632.90	3358.39	725.49	17.52
OP141RTR02	RA	01/02/14	02/27/14	56.02	2.47	1450.8	1548.0	97.2	99.87	97.33	39.2	3358.39	4749.98	1391.59	33.61
OP141RTR02	RA	01/02/14	02/27/14	56.02	2.47	1450.8	1548.0	97.2	99.87	97.33	39.2	3358.39	4749.98	1391.59	33.61
OP141RTR03	RA	02/27/14	04/03/14	34.98	3.60	1508.7	1558.8	50.1	76.45	65.53	45.2	4749.98	5392.82	642.84	15.53
OP141RTR03	RA	02/27/14	04/03/14	34.98	3.60	1508.7	1558.8	50.1	76.45	65.53	45.2	4749.98	5392.82	642.84	15.53
OP142RTR02	RA	04/03/14	05/15/14	42.03	4.74	1443.8	1530.0	86.2	63.65	135.42	32.8	5392.82	6401.74	1008.92	24.37
OP142RTR02	RA	04/03/14	05/15/14	42.03	4.74	1443.8	1530.0	86.2	63.65	135.42	32.8	5392.82	6401.74	1008.92	24.37
OP142RTR03	RA	05/15/14	06/12/14	27.97	6.14	1488.7	1553.7	65.0	51.06	127.29	50.8	6401.74	7133.87	732.13	17.68
OP142RTR04	RA	06/12/14	07/03/14	21.02	6.82	1507.6	1583.0	75.4	65.01	115.99	46.1	7133.87	7734.46	600.59	14.51
OP142RTR04	RA	06/12/14	07/03/14	21.02	6.82	1507.6	1583.0	75.4	65.01	115.99	46.1	7133.87	7734.46	600.59	14.51
OP143RTR02	RA	07/03/14	07/21/14	18.02	9.04	1506.1	1590.9	84.8	64.20	132.09	44.0	7734.46	8250.48	516.02	12.46
OP143RTR03	RA	07/21/14	08/08/14	17.86	9.26	1462.0	1550.7	88.7	68.93	128.69	43.1	8250.48	8741.25	490.77	11.85
OP143RTR04	RA	08/08/14	08/22/14	14.06	9.47	1498.7	1588.6	89.9	92.67	97.01	35.3	8741.25	9103.02	361.77	8.74
OP143RTR04	RA	08/08/14	08/22/14	14.06	9.47	1498.7	1588.6	89.9	92.67	97.01	35.3	8741.25	9103.02	361.77	8.74
OP143RTR05	RA	08/22/14	09/04/14	13.06	8.15	1505.5	1571.7	66.2	83.29	79.48	39.7	9103.02	9447.40	344.38	8.32
OP143RTR06	RA	09/04/14	10/02/14	28.01	6.82	1501.9	1611.3	109.4	82.61	132.43	48.5	9447.40	10133.14	685.74	16.56
OP144RTR02	RA	10/02/14	10/30/14	28.00	5.09	1474.9	1563.0	88.1	83.07	106.06	48.5	133.14	869.00	735.86	17.77
OP144RTR03	RA	10/30/14	12/11/14	41.97	3.22	1512.3	1604.8	92.5	92.19	100.33	41.4	869.00	1969.39	1100.39	26.58
OP144RTR03	RA	10/30/14	12/11/14	41.97	3.22	1512.3	1604.8	92.5	92.19	100.33	41.4	869.00	1969.39	1100.39	26.58
OP144RTR04	RA	12/11/14	12/31/14	19.92	3.51	1519.2	1566.4	47.2	93.80	50.32	29.5	1969.39	2475.68	506.29	12.23

Table A10 – IDEQ HTO Sand Dunes 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121STR02	SD	12/29/11	03/01/12	63.04	2.33	1383.3	1463.8	80.5	103.83	77.53	30.6	6811.79	7986.88	1175.09	28.38
OP121STR03	SD	03/01/12	03/29/12	28.14	3.30	1394.4	1440.6	46.2	88.43	52.24	33.3	7986.88	8545.95	559.07	13.50
OP122STR02	SD	03/29/12	05/10/12	41.84	3.82	1496.6	1572.2	75.6	84.35	89.62	42.6	8546.00	9374.55	828.55	20.01
OP122STR02	SD	03/29/12	05/10/12	41.84	3.82	1496.6	1572.2	75.6	84.35	89.62	42.6	8546.00	9374.55	828.55	20.01
OP122STR03	SD	05/10/12	06/13/12	34.07	4.93	1408.3	1485.7	77.4	76.11	101.70	50.9	9374.55	10103.04	728.49	17.59
OP123STR02	SD	06/28/12	07/19/12	21.03	5.44	1360.0	1443.0	83.0	115.40	71.92	40.7	300.05	766.95	466.90	11.28
OP123STR03	SD	07/19/12	08/09/12	21.25	5.31	1446.0	1517.0	71.0	93.23	76.15	57.1	766.95	1273.41	506.46	12.23
OP123STR04	SD	08/09/12	08/28/12	18.81	4.96	1332.1	1418.2	86.1	102.78	83.77	43.0	1273.41	1869.84	596.43	14.41
OP123STR05	SD	08/28/12	09/27/12	29.96	4.27	1501.7	1581.0	79.3	91.14	87.01	44.6	1869.84	2589.42	719.58	17.38
OP123STR05	SD	08/28/12	09/27/12	29.96	4.27	1501.7	1581.0	79.3	91.14	87.01	44.6	1869.84	2589.42	719.58	17.38
OP124STR02	SD	09/27/12	11/15/12	48.99	3.40	1363.1	1436.3	73.2	104.55	70.02	32.8	2589.42	3316.66	727.24	17.56
OP124STR02	SD	09/27/12	11/15/12	48.99	3.40	1363.1	1436.3	73.2	104.55	70.02	32.8	2589.42	3316.66	727.24	17.56
OP124STR03	SD	11/15/12	12/27/12	42.00	2.69	1410.4	1471.2	60.8	118.70	51.22	48.8	3316.66	3989.08	672.42	16.24
OP124STR03	SD	11/15/12	12/27/12	42.00	2.69	1410.4	1471.2	60.8	118.70	51.22	48.8	3316.66	3989.08	672.42	16.24
OP131STR02	SD	12/27/12	03/14/13	77.00	2.45	1418.7	1495.7	77.0	88.93	86.59	39.2	3989.08	5237.14	1248.06	30.14
OP132STR02	SD	03/28/13	05/23/13	55.97	4.10	1412.3	1491.6	79.3	64.50	122.94	43.2	5456.00	6514.90	1058.90	25.58
OP132STR03	SD	05/23/13	06/18/13	26.17	4.93	1389.4	1440.4	51.0	62.68	81.36	48.9	6514.90	7097.72	582.82	14.08
OP133STR02	SD	06/27/13	07/22/13	25.17	5.44	1477.0	1567.3	90.3	105.17	85.86	30.8	7297.48	7854.84	557.36	13.46
OP133STR03	SD	07/22/13	08/08/13	16.84	5.20	1415.8	1475.9	60.1	93.28	64.43	47.0	7854.84	8292.42	437.58	10.57
OP133STR04	SD	08/08/13	08/29/13	20.98	4.96	1422.0	1515.5	93.5	117.98	79.25	41.6	8292.42	8856.69	564.27	13.63
OP133STR04	SD	08/08/13	08/29/13	20.98	4.96	1422.0	1515.5	93.5	117.98	79.25	41.6	8292.42	8856.69	564.27	13.63
OP133STR05	SD	08/29/13	09/19/13	21.00	4.27	1419.3	1526.8	107.5	179.81	59.79	47.4	8856.69	9351.15	494.46	11.94
OP134STR02	SD	09/26/13	11/21/13	55.99	3.07	1402.1	1494.6	92.5	117.64	78.63	34.5	9505.08	10409.54	904.46	21.84
OP134STR03	SD	11/21/13	01/02/14	41.97	2.31	1498.7	1530.8	32.1	80.33	39.96	33.4	409.54	1020.46	610.92	14.76
OP141STR02	SD	01/02/14	02/27/14	56.03	2.33	1450.8	1512.9	62.1	95.56	64.99	46.1	1020.46	2005.43	984.97	23.79
OP141STR03	SD	02/27/14	04/03/14	34.96	3.30	1385.0	1434.6	49.6	85.71	57.87	30.6	2005.43	2624.70	619.27	14.96
OP142STR02	SD	04/03/14	05/22/14	49.02	4.10	1485.8	1570.5	84.7	67.50	125.48	34.5	2624.70	3705.50	1080.80	26.10
OP142STR03	SD	05/22/14	07/03/14	42.01	5.26	1422.2	1510.9	88.7	63.11	140.55	54.8	3705.50	4649.16	943.66	22.79
OP143STR02	SD	07/03/14	07/21/14	18.13	5.44	1369.1	1442.2	73.1	118.47	61.70	40.2	4649.16	5049.72	400.56	9.67
OP143STR03	SD	07/21/14	08/14/14	23.88	5.20	1512.4	1606.8	94.4	148.27	63.67	43.7	5049.72	5482.12	432.40	10.44
OP143STR04	SD	08/14/14	09/04/14	21.00	4.96	1412.5	1511.6	99.1	151.57	65.38	55.5	5482.12	5947.65	465.53	11.24
OP143STR05	SD	09/04/14	10/02/14	27.98	4.96	1449.5	1535.4	85.9	126.36	67.98	57.6	5947.65	6431.65	484.00	11.69
OP144STR02	SD	10/02/14	11/06/14	34.99	3.74	1458.9	1529.2	70.3	108.95	64.52	38.1	6431.65	7040.92	609.27	14.72
OP144STR03	SD	11/06/14	12/31/14	55.02	2.69	1382.2	1466.8	84.6	94.54	89.49	58.0	7040.92	8215.71	1174.79	28.37

Table A11 – IDEQ HTO Van Buren 2012-2014

Sample ID	Location	Start Date/Time	Stop Date/Time	Days Collected	Average AH ($g\ m^{-3}$)	Start Column Mass (g)	Stop Column Mass (g)	Mass gain (g)	Colllection Efficiency%	Mass Gain with CE (g)	Distillate (mL)	Gas Meter Start	Gas Meter Stop	Volume (ft^3)	Corrected Volume (m^3)
OP121BTR02	VB	12/29/11	02/09/12	41.97	2.86	1363.5	1444.4	80.9	85.98	94.09	36.2	5464.66	6626.48	1161.82	28.06
OP121BTR03	VB	02/09/12	03/13/12	33.08	3.56	1401.3	1460.7	59.4	70.10	84.73	34.4	6626.48	7467.03	840.55	20.30
OP121BTR04	VB	03/13/12	03/29/12	15.90	4.23	1358.6	1409.8	51.2	118.99	43.03	28.1	7467.03	7826.25	359.22	8.68
OP121BTR04	VB	03/13/12	03/29/12	15.90	4.23	1358.6	1409.8	51.2	118.99	43.03	28.1	7467.03	7826.25	359.22	8.68
OP122BTR02	VB	03/29/12	05/03/12	35.07	9.09	1450.1	1529.0	78.9	33.71	234.06	31.7	7826.25	8735.56	909.31	21.96
OP122BTR03	VB	05/03/12	06/07/12	34.99	5.41	1427.9	1509.7	81.8	63.58	128.67	36.1	8735.56	9575.45	839.89	20.29
OP122BTR04	VB	06/07/12	06/28/12	20.98	6.82	1398.8	1444.1	45.3	48.57	93.26	30.4	9575.45	10058.36	482.91	11.66
OP123BTR02	VB	06/28/12	07/19/12	21.02	9.39	1437.9	1525.7	87.8	69.44	126.45	43.9	58.36	533.92	475.56	11.49
OP123BTR02	VB	06/28/12	07/19/12	21.02	9.39	1437.9	1525.7	87.8	69.44	126.45	43.9	58.36	533.92	475.56	11.49
OP123BTR03	VB	07/19/12	08/16/12	27.99	8.45	1448.5	1521.3	72.8	43.71	166.54	46.6	533.92	1229.95	696.03	16.81
OP123BTR04	VB	08/16/12	09/13/12	28.01	6.80	1403.5	1488.5	85.0	64.56	131.66	37.6	1229.95	1913.70	683.75	16.51
OP123BTR05	VB	09/13/12	09/27/12	14.04	6.08	1337.9	1386.2	48.3	71.31	67.74	32.5	1913.70	2307.14	393.44	9.50
OP124BTR02	VB	09/27/12	11/08/12	41.95	4.18	1399.8	1493.7	93.9	84.11	111.65	47.4	2307.14	3250.38	943.24	22.78
OP124BTR03	VB	11/08/12	12/13/12	35.02	3.77	1495.0	1569.8	74.8	92.42	80.94	41.9	3250.38	4008.56	758.18	18.31
OP131BTR02	VB	12/27/12	03/07/13	69.99	2.69	1479.5	1566.5	87.0	76.03	114.42	48.0	4304.32	5806.48	1502.16	36.28
OP131BTR03	VB	03/07/13	03/28/13	21.03	4.23	1390.1	1437.2	47.1	68.69	68.57	32.8	5806.48	6378.97	572.49	13.83
OP132BTR02	VB	03/28/13	05/09/13	41.98	3.56	1435.6	1513.1	77.5	77.74	99.69	37.1	6378.97	7367.89	988.92	23.88
OP132BTR03	VB	05/09/13	06/04/13	26.02	3.77	1397.7	1456.0	58.3	95.41	61.10	39.4	7367.89	7940.27	572.38	13.82
OP132BTR04	VB	06/04/13	06/27/13	23.00	7.31	1421.2	1492.6	71.4	59.18	120.65	45.4	7940.27	8523.13	582.86	14.08
OP133BTR02	VB	06/27/13	07/15/13	18.04	8.69	1331.6	1405.5	73.9	73.11	101.07	33.3	8523.13	8933.88	410.75	9.92
OP133BTR03	VB	07/15/13	08/15/13	30.93	8.92	1359.9	1440.3	80.4	46.19	174.08	47.1	8933.88	9623.07	689.19	16.65
OP133BTR03	VB	07/15/13	08/15/13	30.93	8.92	1359.9	1440.3	80.4	46.19	174.08	47.1	8933.88	9623.07	689.19	16.65
OP133BTR04	VB	08/15/13	09/05/13	20.99	7.80	1400.6	1485.1	84.5	80.64	104.79	46.8	9623.07	10097.52	474.45	11.46
OP133BTR05	VB	09/05/13	09/26/13	21.02	7.95	1433.8	1502.6	68.8	84.06	81.84	38.8	97.52	461.07	363.55	8.78
OP134BTR02	VB	09/26/13	12/05/13	69.97	3.94	1418.3	1505.7	87.4	76.95	113.58	35.1	461.07	1479.11	1018.04	24.59
OP141BTR02	VB	01/02/14	03/12/14	69.00	3.11	1400.3	1497.9	97.6	90.72	107.58	62.0	1990.07	3211.70	1221.63	29.51
OP141BTR03	VB	03/12/14	04/03/14	22.00	3.60	1395.2	1428.7	33.5	68.85	48.66	45.0	3211.70	3689.02	477.32	11.53
OP142BTR02	VB	04/03/14	05/08/14	35.00	4.02	1435.1	1503.9	68.8	68.90	99.86	42.1	3689.02	4566.26	877.24	21.19
OP142BTR03	VB	05/08/14	06/05/14	27.98	5.45	1446.7	1513.4	66.7	60.34	110.54	48.1	4566.26	5282.55	716.29	17.30
OP142BTR03	VB	05/08/14	06/05/14	27.98	5.45	1446.7	1513.4	66.7	60.34	110.54	48.1	4566.26	5282.55	716.29	17.30
OP142BTR04	VB	06/05/14	07/03/14	28.04	6.82	1465.3	1526.9	61.6	68.90	89.40	37.5	5282.55	5745.49	462.94	11.18
OP143BTR02	VB	07/03/14	07/31/14	28.00	9.04	1504.7	1599.7	95.0	51.27	185.30	36.3	5745.49	6469.36	723.87	17.48
OP143BTR03	VB	07/31/14	08/14/14	13.99	9.47	1489.2	1583.4	94.2	89.30	105.48	42.9	6469.36	6862.72	393.36	9.50
OP143BTR04	VB	08/14/14	09/18/14	34.99	8.15	1368.9	1450.8	81.9	47.72	171.64	52.9	6862.71	7606.43	743.72	17.96
OP143BTR05	VB	09/18/14	10/02/14	14.03	6.82	1396.2	1489.1	92.9	108.12	85.93	44.2	7606.43	8051.36	444.93	10.75
OP144BTR02	VB	10/02/14	11/06/14	34.96	5.09	1397.4	1480.6	83.2	82.87	100.40	50.1	8051.36	8747.96	696.60	16.82
OP144BTR03	VB	11/06/14	12/31/14	54.92	3.37	1531.5	1619.2	87.7	83.27	105.32	57.4	8747.96	9851.60	1103.64	26.66

Appendix B - HTO Analysis and Uncertainty taken from Microsoft Excel[22]

Table B1 – EML HTO Analysis – Atomic City 2012-2014

Sample ID	Location ID	Analysis Dat	STD CPI	BKG CP	Sample CPM	Count Time	Sample Volum	STD dpm/n	STD ref da	Efficien	CONC pCi/m	±2 StDev CONC	MDC	Atmospheric HTO	±	σ Atmospheric HTO	Atmospheric HTO with CE	±	σ Atmospheric HTO with CE
OP121ATR02	AC	4/16/2012	81.6	1.53	1.43	130	9	85.07	6/13/2000	0.2039	-0.02455	0.074089	0.129227894	-0.062	±	0.189	-0.095	±	0.288
OP121ATR03	AC	4/17/2012	89.79	4.37	4.96	200	9	85.07	6/13/2000	0.2175	0.135751	0.099391	0.161607873	0.453	±	0.338	0.673	±	0.502
OP122ATR02	AC	7/23/2012	87.29	4.59	4.74	200	9	85.07	6/13/2000	0.2138	0.035118	0.101134	0.168452305	0.133	±	0.384	0.183	±	0.528
OP122ATR03	AC	7/25/2012	80.37	1.54	1.59	130	9	85.07	6/13/2000	0.2038	0.012277	0.0762	0.129655292	0.055	±	0.344	0.084	±	0.519
OP122ATR04	AC	7/25/2012	80.37	1.54	1.65	120	9	85.07	6/13/2000	0.2038	0.027009	0.080068	0.135167048	0.114	±	0.338	0.216	±	0.641
OP123ATR02	AC	9/19/2012	80.12	1.71	2	110	9	85.07	6/13/2000	0.2045	0.070972	0.08989	0.148221831	0.496	±	0.632	0.781	±	0.996
OP123ATR02	AC	9/19/2012	80.12	1.71	1.8	130	9	85.07	6/13/2000	0.2045	0.022026	0.080427	0.135899821	0.154	±	0.563	0.242	±	0.886
OP123ATR03	AC	9/19/2012	80.12	1.71	1.85	130	9	85.07	6/13/2000	0.2045	0.034262	0.080998	0.135899821	0.189	±	0.448	0.345	±	0.817
OP123ATR04	AC	11/8/2012	80.2	1.76	1.7	110	9	85.07	6/13/2000	0.2062	-0.01457	0.086108	0.149073342	-0.077	±	0.458	-0.119	±	0.703
OP123ATR05	AC	11/8/2012	84.35	4.37	4.98	200	9	85.07	6/13/2000	0.2102	0.14523	0.102955	0.167224332	0.672	±	0.485	1.035	±	0.748
OP124ATR02	AC	1/18/2013	82.42	4.37	4.61	200	9	85.07	6/13/2000	0.2074	0.057915	0.102266	0.169491846	0.245	±	0.434	0.284	±	0.503
OP124ATR03	AC	1/18/2013	82.42	4.37	4.56	200	9	85.07	6/13/2000	0.2074	0.045849	0.101981	0.169491846	0.204	±	0.456	0.219	±	0.488
OP131ATR02	AC	4/30/2013	78.020	1.310	1.73	110	9	85.07	6/13/2000	0.2071	0.10151	0.080358	0.128864087	0.221	±	0.178	0.294	±	0.236
OP131ATR03	AC	4/30/2013	78.020	1.310	1.49	130	9	85.07	6/13/2000	0.2071	0.043504	0.070941	0.118098807	0.145	±	0.237	0.175	±	0.287
OP132ATR02	AC	7/26/2013	91.800	1.480	1.72	120	9	106.40	6/13/2000	0.1976	0.060796	0.082733	0.136816488	0.198	±	0.270	0.254	±	0.347
OP132ATR03	AC	7/26/2013	91.800	1.480	1.62	130	9	106.40	6/13/2000	0.1976	0.035464	0.078235	0.131233405	0.175	±	0.387	0.245	±	0.542
OP132ATR04	AC	7/26/2013	98.930	4.410	4.39	200	9	106.40	6/13/2000	0.2068	-0.00484	0.10155	0.170779195	-0.027	±	0.570	-0.041	±	0.870
OP133ATR02	AC	10/28/13	85.60	1.45	1.37	130	9	106.40	6/13/2000	0.1868	-0.02037	0.078876	0.137280929	-0.155	±	0.599	-0.213	±	0.825
OP133ATR03	AC	10/28/13	85.60	1.45	1.71	130	9	106.40	6/13/2000	0.1868	0.070742	0.083502	0.137280929	0.418	±	0.496	0.835	±	0.993
OP133ATR04	AC	10/14/13	86.31	1.94	1.76	120	9	106.40	6/13/2000	0.1869	-0.04821	0.094067	0.164754566	-0.292	±	0.571	-0.439	±	0.859
OP133ATR05	AC	10/11/13	97.07	4.65	4.56	200	9	106.40	6/13/2000	0.2046	-0.02202	0.104994	0.177141536	-0.188	±	0.897	-0.205	±	0.979
OP134ATR02	AC	01/24/14	86.40	1.46	1.60	120	9	106.40	6/13/2000	0.1911	0.036666	0.083644	0.140533578	0.161	±	0.367	0.188	±	0.430
OP134ATR03	AC	01/24/14	86.40	1.46	1.45	120	9	106.40	6/13/2000	0.1911	-0.00262	0.081568	0.140533578	-0.008	±	0.253	-0.008	±	0.235
OP141ATR02	AC	04/29/14	86.21	1.49	1.30	130	9	106.40	6/13/2000	0.1934	-0.04916	0.075815	0.134486445	-0.083	±	0.128	-0.205	±	0.318
OP142ATR02	AC	07/31/14	82.42	1.20	1.56	130	9	106.40	6/13/2000	0.1881	0.095782	0.077535	0.12466703	0.336	±	0.276	0.451	±	0.371
OP142ATR03	AC	07/31/14	82.42	1.20	1.41	130	9	106.40	6/13/2000	0.1881	0.055873	0.075398	0.12466703	0.216	±	0.293	0.519	±	0.705
OP142ATR03	AC	07/31/14	82.42	1.20	1.35	130	9	106.40	6/13/2000	0.1881	0.039909	0.074526	0.12466703	0.154	±	0.289	0.371	±	0.695
OP142ATR04	AC	07/30/14	90.83	4.58	4.60	200	9	106.40	6/13/2000	0.1997	0.005012	0.107372	0.180103662	0.028	±	0.607	0.040	±	0.859
OP143ATR02	AC	09/29/14	90.07	4.63	4.73	200	9	106.40	6/13/2000	0.1997	0.025059	0.108421	0.181069367	0.093	±	0.403	0.272	±	1.178
OP143ATR03	AC	10/24/14	88.92	4.10	4.51	200	9	106.40	6/13/2000	0.1990	0.103094	0.104344	0.171176334	0.309	±	0.316	0.824	±	0.842
OP144ATR02	AC	01/22/15	86.00	4.43	4.53	200	9	106.40	6/13/2000	0.1941	0.024926	0.109178	0.182398228	0.123	±	0.537	0.149	±	0.652
OP144ATR02	AC	01/22/15	86.00	4.43	4.77	200	9	106.40	6/13/2000	0.1941	0.086813	0.11063	0.182398228	0.427	±	0.547	0.518	±	0.664
OP144ATR03	AC	01/22/15	86.00	4.43	4.96	180	9	106.40	6/13/2000	0.1941	0.135806	0.117812	0.192463837	0.435	±	0.382	0.537	±	0.472

[22] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

Table B2 – EML HTO Analysis – Craters of the Moon 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121CTR02	CM	4/3/2012	81.66	1.39	1.46	130	9	85.07	6/13/2000	0.2040	0.017176	0.072663	0.123353208	0.049	±	0.208	0.053	±	0.224
OP121CTR03	CM	4/17/2012	89.79	4.37	4.97	200	9	85.07	6/13/2000	0.2175	0.138052	0.099444	0.161607873	0.522	±	0.383	0.610	±	0.448
OP122CTR02	CM	7/25/2012	80.37	1.54	1.84	130	9	85.07	6/13/2000	0.2038	0.073662	0.079184	0.129655292	0.288	±	0.312	0.319	±	0.345
OP122CTR02	CM	7/25/2012	80.37	1.54	1.78	130	9	85.07	6/13/2000	0.2038	0.05893	0.078478	0.129655292	0.230	±	0.309	0.255	±	0.341
OP122CTR03	CM	7/23/2012	87.29	4.59	4.75	200	9	85.07	6/13/2000	0.2138	0.03746	0.101189	0.168452305	0.176	±	0.477	0.205	±	0.555
OP122CTR04	CM	7/23/2012	87.29	4.59	4.74	200	9	85.07	6/13/2000	0.2138	0.035118	0.101134	0.168452305	0.147	±	0.424	0.205	±	0.592
OP122CTR04	CM	7/23/2012	87.29	4.59	4.7	200	9	85.07	6/13/2000	0.2138	0.025753	0.100917	0.168452305	0.108	±	0.423	0.151	±	0.591
OP123CTR02	CM	9/19/2012	80.12	1.71	1.6	130	9	85.07	6/13/2000	0.2045	-0.02692	0.078102	0.135899821	-0.179	±	0.521	-0.219	±	0.636
OP123CTR03	CM	9/19/2012	80.12	1.71	1.86	130	9	85.07	6/13/2000	0.2045	0.03671	0.081111	0.135899821	0.157	±	0.348	0.268	±	0.594
OP123CTR04	CM	9/19/2012	85.64	4.5	4.55	200	9	85.07	6/13/2000	0.2116	0.011825	0.100616	0.168515943	0.054	±	0.459	0.076	±	0.650
OP123CTR05	CM	11/8/2012	80.2	1.76	1.7	130	9	85.07	6/13/2000	0.2062	-0.01457	0.079208	0.136686682	-0.061	±	0.333	-0.081	±	0.443
OP124CTR02	CM	01/18/13	82.42	4.37	4.48	200	9	85.07	6/13/2000	0.2074	0.026544	0.101523	0.169491846	0.075	±	0.288	0.115	±	0.440
OP124CTR03	CM	01/18/13	82.42	4.37	4.32	190	9	85.07	6/13/2000	0.2074	-0.01207	0.103214	0.173982114	-0.035	±	0.299	-0.050	±	0.424
OP131CTR02	CM	04/30/13	78.020	1.310	1.38	100	9	85.07	6/13/2000	0.2071	0.016918	0.079281	0.135458607	0.040	±	0.190	0.041	±	0.191
OP131CTR03	CM	04/30/13	78.020	1.310	1.74	120	9	85.07	6/13/2000	0.2071	0.103927	0.077064	0.123135266	0.292	±	0.220	0.334	±	0.252
OP131CTR04	CM	04/30/13	80.07	4.38	4.51	130	9	85.07	6/13/2000	0.2043	0.031843	0.12811	0.214626327	0.110	±	0.444	0.111	±	0.445
OP132CTR02	CM	07/26/13	91.800	1.480	1.52	130	9	106.40	6/13/2000	0.1976	0.010133	0.076963	0.131233405	0.032	±	0.246	0.039	±	0.296
OP132CTR03	CM	07/26/13	91.800	1.480	1.45	130	9	106.40	6/13/2000	0.1976	-0.0076	0.07606	0.131233405	-0.035	±	0.347	-0.043	±	0.433
OP132CTR04	CM	07/26/13	98.930	4.410	4.61	200	9	106.40	6/13/2000	0.2068	0.048412	0.102811	0.170779195	0.249	±	0.530	0.330	±	0.702
OP133CTR02	CM	10/28/13	85.60	1.45	1.40	130	9	106.40	6/13/2000	0.1868	-0.01233	0.079295	0.137280929	-0.053	±	0.341	-0.089	±	0.573
OP133CTR03	CM	10/03/13	84.69	1.54	1.96	110	9	106.40	6/13/2000	0.1838	0.114343	0.097124	0.156816914	0.480	±	0.414	0.796	±	0.686
OP133CTR04	CM	10/11/13	97.07	4.65	4.75	200	9	106.40	6/13/2000	0.2046	0.024464	0.106071	0.177141536	0.144	±	0.626	0.164	±	0.712
OP133CTR05	CM	10/11/13	97.07	4.65	4.61	200	9	106.40	6/13/2000	0.2046	-0.00979	0.105278	0.177141536	-0.063	±	0.683	-0.056	±	0.601
OP134CTR02	CM	02/03/14	91.60	4.60	4.48	200	9	106.40	6/13/2000	0.1960	-0.03064	0.108797	0.183888731	-0.135	±	0.478	-0.144	±	0.512
OP134CTR03	CM	01/24/14	86.40	1.46	1.28	130	9	106.40	6/13/2000	0.1911	-0.04714	0.076045	0.134797362	-0.139	±	0.225	-0.157	±	0.254
OP134CTR03	CM	01/24/14	86.40	1.46	1.48	120	9	106.40	6/13/2000	0.1911	0.005238	0.081988	0.140533578	0.015	±	0.241	0.017	±	0.273
OP134CTR04	CM	01/24/14	86.40	1.46	1.57	130	9	106.40	6/13/2000	0.1911	0.028809	0.079968	0.134797362	0.084	±	0.234	0.076	±	0.210
OP141CTR02	CM	04/29/14	86.21	1.49	1.32	130	9	106.40	6/13/2000	0.1934	-0.04399	0.076086	0.134486445	-0.114	±	0.198	-0.147	±	0.256
OP141CTR03	CM	04/29/14	94.45	4.45	4.56	200	9	106.40	6/13/2000	0.2055	0.026793	0.103398	0.172612367	0.084	±	0.325	0.114	±	0.439
OP141CTR04	CM	04/29/14	92.45	4.45	4.54	200	9	106.40	6/13/2000	0.2009	0.02242	0.105631	0.176535376	0.079	±	0.373	0.092	±	0.435
OP142CTR02	CM	07/30/14	90.83	4.58	4.31	200	9	106.40	6/13/2000	0.1997	-0.06766	0.105662	0.180103662	-0.106	±	0.166	-0.320	±	0.501
OP143CTR02	CM	09/29/14	90.07	4.63	4.11	200	9	106.40	6/13/2000	0.1997	-0.13031	0.104769	0.181069367	-0.623	±	0.509	-1.019	±	0.832
OP143CTR03	CM	09/25/14	88.12	4.34	4.53	200	9	106.40	6/13/2000	0.1957	0.048585	0.107703	0.179001211	0.418	±	0.928	0.484	±	1.074
OP143CTR03	CM	09/25/14	88.12	4.34	4.36	200	9	106.40	6/13/2000	0.1957	0.005114	0.106666	0.179001211	0.044	±	0.918	0.051	±	1.062
OP143CTR04	CM	10/24/14	88.92	4.10	4.46	200	9	106.40	6/13/2000	0.1990	0.090522	0.10404	0.171176334	0.687	±	0.796	0.901	±	1.043
OP143CTR05	CM	10/20/14	82.61	1.40	1.49	130	9	106.40	6/13/2000	0.1905	0.023651	0.078363	0.132560273	0.146	±	0.485	0.235	±	0.781
OP143CTR06	CM	10/20/14	82.61	1.40	1.25	130	9	106.40	6/13/2000	0.1905	-0.03942	0.075039	0.132560273	-0.184	±	0.351	-0.270	±	0.515
OP144CTR02	CM	01/19/15	79.45	1.43	1.79	130	9	106.40	6/13/2000	0.1856	0.097099	0.084898	0.137445934	0.176	±	0.156	0.450	±	0.398
OP144CTR03	CM	01/22/15	86.05	4.53	4.73	200	9	106.40	6/13/2000	0.1940	0.051604	0.111038	0.184451233	0.074	±	0.159	0.200	±	0.431

Table B3 – EML HTO Analysis – Experimental Field Station 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121ETR02	EFS	4/17/2012	89.79	4.37	5.04	200	9	85.07	6/13/2000	0.2175	0.154158	0.099816	0.161607873	0.172	±	0.114	0.584	±	0.387
OP121ETR02	EFS	4/26/2012	89.86	4.58	4.75	200	9	85.07	6/13/2000	0.2175	0.039125	0.099416	0.165412857	0.044	±	0.111	0.148	±	0.377
OP122ETR02	EFS	7/25/2012	80.37	1.54	2.3	130	9	85.07	6/13/2000	0.2038	0.186611	0.084401	0.129655292	0.667	±	0.316	1.989	±	0.942
OP122ETR02	EFS	7/25/2012	80.37	1.54	2.52	130	9	85.07	6/13/2000	0.2038	0.24063	0.086785	0.129655292	0.860	±	0.333	2.564	±	0.992
OP122ETR03	EFS	7/25/2012	80.37	1.54	2.31	130	9	85.07	6/13/2000	0.2038	0.189066	0.084511	0.129655292	0.950	±	0.445	1.166	±	0.546
OP122ETR03	EFS	8/3/2012	86.57	4.53	5.35	200	9	85.07	6/13/2000	0.2124	0.193197	0.104732	0.168428749	0.971	±	0.543	1.191	±	0.667
OP122ETR04	EFS	8/3/2012	86.57	4.53	5.19	200	9	85.07	6/13/2000	0.2124	0.1555	0.10388	0.168428749	0.666	±	0.454	1.243	±	0.849
OP122ETR04	EFS	7/25/2012	80.37	1.54	2.31	130	9	85.07	6/13/2000	0.2038	0.189066	0.084511	0.129655292	0.809	±	0.379	1.512	±	0.708
OP123ETR02	EFS	9/19/2012	80.12	1.71	2.11	130	9	85.07	6/13/2000	0.2045	0.097892	0.083903	0.135899821	0.833	±	0.724	1.078	±	0.936
OP123ETR03	EFS	9/19/2012	80.12	1.71	2.71	120	9	85.07	6/13/2000	0.2045	0.244731	0.093938	0.141665843	0.681	±	0.278	2.425	±	0.991
OP123ETR03	EFS	11/15/2012	81.23	1.97	3.09	120	9	85.07	6/13/2000	0.2086	0.268784	0.09856	0.14870915	0.747	±	0.293	2.663	±	1.045
OP123ETR04	EFS	9/19/2012	85.64	4.5	5.01	200	9	85.07	6/13/2000	0.2116	0.120613	0.103141	0.168515943	0.689	±	0.597	1.062	±	0.920
OP123ETR05	EFS	11/8/2012	84.35	4.37	5.4	200	9	85.07	6/13/2000	0.2102	0.245225	0.105242	0.167224332	1.271	±	0.574	1.748	±	0.789
OP123ETR05	EFS	11/15/2012	81.23	1.97	3	130	9	85.07	6/13/2000	0.2086	0.247186	0.093847	0.142670851	1.281	±	0.518	1.762	±	0.713
OP124ETR02	EFS	01/18/13	82.42	4.37	4.95	200	9	85.07	6/13/2000	0.2074	0.13996	0.104184	0.169491846	0.582	±	0.441	0.686	±	0.520
OP124ETR03	EFS	01/18/13	82.42	4.37	4.78	200	9	85.07	6/13/2000	0.2074	0.098938	0.103229	0.169491846	0.458	±	0.482	0.515	±	0.542
OP124ETR03	EFS	01/29/13	79.25	1.76	2.23	130	9	85.07	6/13/2000	0.2063	0.114042	0.085018	0.136622316	0.528	±	0.400	0.594	±	0.450
OP124ETR03	EFS	01/18/13	82.42	4.37	5.15	200	9	85.07	6/13/2000	0.2074	0.188223	0.105296	0.169491846	0.871	±	0.502	0.980	±	0.565
OP124ETR04	EFS	01/18/13	82.42	4.37	4.77	200	9	85.07	6/13/2000	0.2074	0.096524	0.103173	0.169491846	0.398	±	0.429	0.352	±	0.379
OP124ETR04	EFS	01/18/13	82.42	4.37	4.84	180	9	85.07	6/13/2000	0.2074	0.113416	0.109169	0.17884653	0.467	±	0.455	0.414	±	0.402
OP131ETR02	EFS	04/30/13	78.020	1.310	1.60	130	9	85.07	6/13/2000	0.2071	0.07009	0.072321	0.118098807	0.176	±	0.183	0.203	±	0.211
OP131ETR02	EFS	04/30/13	78.020	1.310	1.65	120	9	85.07	6/13/2000	0.2071	0.082175	0.075918	0.123135266	0.206	±	0.193	0.238	±	0.222
OP132ETR02	EFS	07/26/13	91.800	1.480	1.90	130	9	106.40	6/13/2000	0.1976	0.106393	0.081692	0.131233405	0.388	±	0.303	0.444	±	0.347
OP132ETR02	EFS	07/26/13	91.800	1.480	2.07	130	9	106.40	6/13/2000	0.1976	0.149456	0.083721	0.131233405	0.545	±	0.315	0.624	±	0.360
OP132ETR03	EFS	07/26/13	91.800	1.480	1.87	130	9	106.40	6/13/2000	0.1976	0.098793	0.081329	0.131233405	0.492	±	0.411	0.671	±	0.560
OP132ETR03	EFS	07/26/13	91.800	1.480	1.75	130	9	106.40	6/13/2000	0.1976	0.068395	0.079859	0.131233405	0.341	±	0.401	0.464	±	0.546
OP132ETR04	EFS	07/26/13	98.930	4.410	4.93	200	9	106.40	6/13/2000	0.2068	0.125871	0.104619	0.170779195	0.649	±	0.547	1.079	±	0.909
OP132ETR04	EFS	07/26/13	98.930	4.410	5.17	200	9	106.40	6/13/2000	0.2068	0.183965	0.105955	0.170779195	0.949	±	0.562	1.577	±	0.935
OP133ETR02	EFS	10/28/13	85.60	1.45	1.90	130	9	106.40	6/13/2000	0.1868	0.121654	0.085979	0.137280929	0.773	±	0.557	1.436	±	1.035
OP133ETR02	EFS	10/28/13	85.60	1.45	1.77	130	9	106.40	6/13/2000	0.1868	0.086819	0.084292	0.137280929	0.552	±	0.541	1.025	±	1.005
OP133ETR03	EFS	10/03/13	84.69	1.54	2.53	100	9	106.40	6/13/2000	0.1838	0.269522	0.109847	0.164814312	1.187	±	0.511	2.455	±	1.058
OP133ETR03	EFS	10/03/13	84.69	1.54	2.68	120	9	106.40	6/13/2000	0.1838	0.310359	0.102107	0.14986738	1.366	±	0.489	2.827	±	1.011
OP133ETR04	EFS	10/14/13	86.31	1.94	1.89	200	9	106.40	6/13/2000	0.1869	-0.01339	0.074133	0.126562201	-0.109	±	0.605	-0.123	±	0.683
OP133ETR05	EFS	10/18/13	95.88	4.37	4.78	200	9	106.40	6/13/2000	0.2028	0.101189	0.105578	0.173348099	0.789	±	0.831	0.943	±	0.993
OP134ETR02	EFS	01/24/14	86.40	1.46	2.20	120	9	106.40	6/13/2000	0.1911	0.193806	0.091478	0.140533578	0.868	±	0.428	0.995	±	0.490
OP134ETR02	EFS	02/03/14	85.61	1.57	2.39	120	9	106.40	6/13/2000	0.1894	0.216723	0.096024	0.146844263	0.971	±	0.451	1.113	±	0.517
OP134ETR03	EFS	01/24/14	86.40	1.46	1.69	130	9	106.40	6/13/2000	0.1911	0.060237	0.081536	0.134797362	0.160	±	0.218	0.202	±	0.275
OP141ETR02	EFS	04/29/14	86.21	1.49	1.39	120	9	106.40	6/13/2000	0.1934	-0.02588	0.080173	0.140207181	-0.073	±	0.225	-0.094	±	0.293
OP141ETR02	EFS	04/29/14	86.21	1.49	1.43	130	9	106.40	6/13/2000	0.1934	-0.01553	0.077561	0.134486445	-0.044	±	0.217	-0.057	±	0.283
OP141ETR03	EFS	04/29/14	86.21	1.49	1.85	130	9	106.40	6/13/2000	0.1934	0.093153	0.082952	0.134486445	0.253	±	0.228	0.393	±	0.354
OP141ETR03	EFS	04/29/14	86.21	1.49	2.04	130	9	106.40	6/13/2000	0.1934	0.142317	0.085278	0.134486445	0.387	±	0.238	0.601	±	0.370
OP142ETR02	EFS	08/04/14	90.06	4.46	4.96	200	9	106.40	6/13/2000	0.1984	0.126146	0.109507	0.178985077	0.509	±	0.448	0.595	±	0.523
OP142ETR02	EFS	07/31/14	82.42	1.20	2.09	130	9	106.40	6/13/2000	0.1881	0.236795	0.084652	0.12466703	0.956	±	0.367	1.116	±	0.428
OP142ETR03	EFS	07/31/14	82.42	1.20	2.36	130	9	106.40	6/13/2000	0.1881	0.308631	0.088057	0.12466703	1.270	±	0.403	1.972	±	0.627
OP142ETR03	EFS	07/31/14	82.42	1.20	1.93	130	9	106.40	6/13/2000	0.1881	0.194225	0.082568	0.12466703	0.799	±	0.358	1.241	±	0.555
OP142ETR04	EFS	07/30/14	90.83	4.58	4.98	200	9	106.40	6/13/2000	0.1997	0.100234	0.109571	0.180103662	0.605	±	0.667	0.801	±	0.883
OP143ETR02	EFS	10/08/14	88.50	4.44	5.10	200	9	106.40	6/13/2000	0.1968	0.167871	0.111102	0.180047439	1.109	±	0.750	1.779	±	1.204
OP143ETR02	EFS	09/25/14	88.12	4.34	5.32	200	9	106.40	6/13/2000	0.1957	0.250598	0.112397	0.179001211	1.655	±	0.778	2.656	±	1.248
OP143ETR03	EFS	10/08/14	88.50	4.44	5.11	200	9	106.40	6/13/2000	0.1968	0.170414	0.11116	0.180047439	1.921	±	1.281	1.892	±	1.262
OP143ETR03	EFS	09/25/14	88.12	4.34	5.10	200	9	106.40	6/13/2000	0.1957	0.194341	0.11111	0.179001211	2.191	±	1.289	2.158	±	1.270
OP143ETR04	EFS	10/24/14	88.92	4.10	5.15	200	9	106.40	6/13/2000	0.1990	0.264021	0.108152	0.171176334	1.963	±	0.850	2.523	±	1.092
OP143ETR04	EFS	10/24/14	88.92	4.10	4.87	200	9	106.40	6/13/2000	0.1990	0.193616	0.106503	0.171176334	1.439	±	0.817	1.850	±	1.050
OP143ETR05	EFS	10/20/14	82.61	1.40	1.80	130	9	106.40	6/13/2000	0.1905	0.105115	0.082459	0.132560273	0.741	±	0.591	0.840	±	0.670
OP143ETR05	EFS	10/20/14	82.61	1.40	1.85	120	9	106.40	6/13/2000	0.1905	0.118255	0.086494	0.138205929	0.834	±	0.621	0.946	±	0.704
OP144ETR02	EFS	01/22/15	80.44	1.62	2.02	130	9	106.40	6/13/2000	0.1876	0.106743	0.089307	0.14438237	0.544	±	0.462	0.637	±	0.540
OP144ETR02	EFS	01/22/15	86.05	4.53	5.29	200	9	106.40	6/13/2000	0.1940	0.194804	0.114317	0.184451233	0.993	±	0.599	1.163	±	0.701
OP144ETR03	EFS	01/22/15	86.00	4.43	4.78	200	9	106.40	6/13/2000	0.1941	0.089392	0.11069	0.182398228	0.308	±	0.384	0.353	±	0.440
OP144ETR04	EFS	01/19/15	79.45	1.43	1.41	130	9	106.40	6/13/2000	0.1856	-0.00539	0.079731	0.137445934	-0.022	±	0.320	-0.022	±	0.328

Table B4 – EML HTO Analysis – Fort Hall 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121NTR02	FH	4/3/2012	81.66	1.39	1.49	130	9	85.07	6/13/2000	0.2040	0.024538	0.073045	0.123353208	0.083	±	0.247	0.087	±	0.260
OP121NTR03	FH	4/17/2012	89.79	4.37	4.84	200	9	85.07	6/13/2000	0.2175	0.108141	0.09875	0.161607873	0.395	±	0.365	0.451	±	0.417
OP122NTR02	FH	7/23/2012	87.29	4.59	4.65	200	9	85.07	6/13/2000	0.2138	0.014047	0.100645	0.168452305	0.072	±	0.519	0.069	±	0.492
OP122NTR03	FH	7/23/2012	87.29	4.59	4.46	200	9	85.07	6/13/2000	0.2138	-0.03044	0.099605	0.168452305	-0.145	±	0.476	-0.153	±	0.500
OP122NTR04	FH	7/25/2012	80.37	1.54	1.71	130	9	85.07	6/13/2000	0.2038	0.041742	0.077647	0.129655292	0.286	±	0.533	0.242	±	0.452
OP122NTR05	FH	7/23/2012	87.29	4.59	4.77	200	9	85.07	6/13/2000	0.2138	0.042142	0.101297	0.168452305	0.269	±	0.649	0.277	±	0.667
OP123NTR02	FH	9/19/2012	80.12	1.71	1.67	130	9	85.07	6/13/2000	0.2045	-0.00979	0.078923	0.135899821	-0.050	±	0.405	-0.086	±	0.689
OP123NTR03	FH	9/19/2012	85.64	4.5	4.26	200	9	85.07	6/13/2000	0.2116	-0.05676	0.09899	0.168515943	-0.252	±	0.440	-0.441	±	0.772
OP123NTR04	FH	11/8/2012	80.2	1.76	1.57	100	9	85.07	6/13/2000	0.2062	-0.04612	0.088598	0.156655596	-0.239	±	0.460	-0.290	±	0.558
OP123NTR04	FH	11/8/2012	84.35	4.37	4.56	200	9	85.07	6/13/2000	0.2102	0.045236	0.100616	0.167224332	0.234	±	0.522	0.284	±	0.634
OP124NTR02	FH	01/18/13	82.42	4.37	4.63	200	9	85.07	6/13/2000	0.2074	0.062741	0.10238	0.169491846	0.319	±	0.523	0.282	±	0.463
OP124NTR03	FH	01/18/13	82.42	4.37	4.60	200	9	85.07	6/13/2000	0.2074	0.055502	0.102209	0.169491846	0.298	±	0.551	0.245	±	0.453
OP124NTR04	FH	01/18/13	82.42	4.37	4.39	200	9	85.07	6/13/2000	0.2074	0.004826	0.101005	0.169491846	0.022	±	0.463	0.020	±	0.414
OP131NTR02	FH	04/30/13	78.020	1.310	1.34	130	9	85.07	6/13/2000	0.2071	0.007251	0.069015	0.118098807	0.021	±	0.197	0.025	±	0.242
OP131NTR03	FH	04/30/13	78.020	1.310	1.44	120	9	85.07	6/13/2000	0.2071	0.03142	0.073176	0.123135266	0.117	±	0.274	0.138	±	0.321
OP132NTR02	FH	07/26/13	91.800	1.480	1.50	130	9	106.40	6/13/2000	0.1976	0.005066	0.076706	0.131233405	0.022	±	0.338	0.023	±	0.349
OP132NTR03	FH	07/26/13	98.930	4.410	4.18	200	9	106.40	6/13/2000	0.2068	-0.05567	0.100331	0.170779195	-0.337	±	0.609	-0.302	±	0.545
OP132NTR04	FH	07/23/13	92.54	1.49	1.50	120	9	106.40	6/13/2000	0.1991	0.002514	0.079367	0.136221212	0.018	±	0.566	0.016	±	0.517
OP133NTR02	FH	10/28/13	85.60	1.45	1.58	120	9	106.40	6/13/2000	0.1868	0.035907	0.085103	0.143123926	0.350	±	0.832	0.280	±	0.666
OP133NTR03	FH	10/03/13	84.69	1.54	1.64	130	9	106.40	6/13/2000	0.1838	0.027224	0.085159	0.143756183	0.237	±	0.743	0.213	±	0.666
OP133NTR04	FH	10/11/13	97.07	4.65	4.48	200	9	106.40	6/13/2000	0.2046	-0.04159	0.104537	0.177141536	-0.313	±	0.787	-0.300	±	0.755
OP133NTR05	FH	10/14/13	86.31	1.94	1.77	130	9	106.40	6/13/2000	0.1869	-0.04553	0.090498	0.158063067	-0.499	±	0.995	-0.278	±	0.554
OP134NTR02	FH	02/03/14	85.61	1.57	2.10	90	9	106.40	6/13/2000	0.1894	0.140077	0.106741	0.170627353	0.598	±	0.463	0.624	±	0.484
OP134NTR02	FH	01/24/14	86.40	1.46	2.65	130	9	106.40	6/13/2000	0.1911	0.31166	0.093135	0.134797362	1.330	±	0.439	1.389	±	0.458
OP134NTR03	FH	02/10/14	91.32	4.53	4.70	200	9	106.40	6/13/2000	0.1958	0.04346	0.109838	0.18275469	0.122	±	0.310	0.146	±	0.369
OP134NTR03	FH	02/10/14	91.32	4.53	4.62	200	9	106.40	6/13/2000	0.1958	0.023008	0.109361	0.18275469	0.065	±	0.308	0.077	±	0.367
OP141NTR02	FH	04/29/14	86.21	1.49	1.70	120	9	106.40	6/13/2000	0.1934	0.054339	0.084378	0.140207181	0.193	±	0.301	0.197	±	0.308
OP141NTR03	FH	04/29/14	92.45	4.45	4.71	190	9	106.40	6/13/2000	0.2009	0.064769	0.109395	0.181211441	0.243	±	0.412	0.264	±	0.448
OP142NTR02	FH	07/30/14	90.83	4.58	4.55	200	9	106.40	6/13/2000	0.1997	-0.00752	0.107079	0.180103662	-0.036	±	0.514	-0.033	±	0.463
OP142NTR03	FH	07/30/14	90.83	4.58	4.45	200	9	106.40	6/13/2000	0.1997	-0.03258	0.106491	0.180103662	-0.167	±	0.546	-0.185	±	0.606
OP142NTR03	FH	07/30/14	90.83	4.58	3.96	200	9	106.40	6/13/2000	0.1997	-0.15536	0.103561	0.180103662	-0.796	±	0.542	-0.883	±	0.602
OP142NTR04	FH	07/31/14	82.42	1.20	1.33	130	9	106.40	6/13/2000	0.1881	0.034588	0.074234	0.12466703	0.104	±	0.223	0.218	±	0.468
OP142NTR05	FH	07/31/14	82.42	1.20	1.37	130	9	106.40	6/13/2000	0.1881	0.04523	0.074818	0.12466703	0.385	±	0.640	0.285	±	0.473
OP143NTR02	FH	09/29/14	90.07	4.63	4.62	200	9	106.40	6/13/2000	0.1997	-0.00251	0.107782	0.181069367	-0.023	±	1.005	-0.019	±	0.805
OP143NTR03	FH	09/25/14	88.12	4.34	4.63	200	9	106.40	6/13/2000	0.1957	0.074156	0.108308	0.179001211	0.729	±	1.070	0.545	±	0.800
OP143NTR04	FH	10/24/14	88.92	4.10	4.76	200	9	106.40	6/13/2000	0.1990	0.165956	0.105848	0.171176334	1.611	±	1.052	1.199	±	0.783
OP143NTR05	FH	10/20/14	82.61	1.40	1.61	130	9	106.40	6/13/2000	0.1905	0.055186	0.079974	0.132560273	0.321	±	0.467	0.391	±	0.570
OP144NTR02	FH	01/22/15	86.00	4.43	4.60	200	9	106.40	6/13/2000	0.1941	0.042977	0.109603	0.182398228	0.265	±	0.676	0.211	±	0.538
OP144NTR03	FH	01/22/15	86.00	4.43	4.40	200	9	106.40	6/13/2000	0.1941	-0.0086	0.108383	0.182398228	-0.039	±	0.495	-0.035	±	0.442
OP144NTR04	FH	01/19/15	79.45	1.43	1.30	130	9	106.40	6/13/2000	0.1856	-0.03506	0.078172	0.137445934	-0.163	±	0.364	-0.113	±	0.252

Table B5 – EML HTO Analysis – Howe 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121HTR02	HW	4/3/2012	81.66	1.39	1.59	130	9	85.07	6/13/2000	0.2040	0.049076	0.074302	0.123353208	0.136	±	0.207	0.134	±	0.204
OP121HTR03	HW	4/17/2012	89.79	4.37	4.56	200	9	85.07	6/13/2000	0.2175	0.043716	0.097237	0.161607873	0.154	±	0.342	0.169	±	0.377
OP122HTR02	HW	7/25/2012	80.37	1.54	1.61	130	9	85.07	6/13/2000	0.2038	0.017188	0.076443	0.129655292	0.063	±	0.279	0.073	±	0.324
OP122HTR03	HW	7/25/2012	80.37	1.54	1.58	130	9	85.07	6/13/2000	0.2038	0.009822	0.076078	0.129655292	0.043	±	0.332	0.053	±	0.410
OP122HTR04	HW	7/25/2012	80.37	1.54	1.81	130	9	85.07	6/13/2000	0.2038	0.066296	0.078832	0.129655292	0.391	±	0.468	0.409	±	0.490
OP123HTR02	HW	9/19/2012	80.12	1.71	1.8	130	9	85.07	6/13/2000	0.2045	0.022026	0.080427	0.135899821	0.188	±	0.688	0.140	±	0.513
OP123HTR03	HW	9/19/2012	80.12	1.71	1.8	120	9	85.07	6/13/2000	0.2045	0.022026	0.083711	0.141665843	0.151	±	0.573	0.134	±	0.511
OP123HTR04	HW	9/19/2012	85.64	4.5	4.43	200	9	85.07	6/13/2000	0.2116	-0.01655	0.099946	0.168515943	-0.110	±	0.666	-0.096	±	0.581
OP123HTR04	HW	9/19/2012	85.64	4.5	4.34	200	9	85.07	6/13/2000	0.2116	-0.03784	0.099441	0.168515943	-0.252	±	0.664	-0.220	±	0.579
OP123HTR05	HW	11/8/2012	80.2	1.76	1.97	100	9	85.07	6/13/2000	0.2062	0.050979	0.093768	0.156655596	0.236	±	0.435	0.255	±	0.471
OP124HTR02	HW	01/18/13	82.42	4.37	4.63	200	9	85.07	6/13/2000	0.2074	0.062741	0.10238	0.169491846	0.256	±	0.420	0.275	±	0.451
OP124HTR03	HW	01/18/13	82.42	4.37	4.37	200	9	85.07	6/13/2000	0.2074	0	0.10089	0.169491846	0.000	±	0.409	0.000	±	0.318
OP131HTR02	HW	04/30/13	78.020	1.310	1.31	130	9	85.07	6/13/2000	0.2071	0	0.068623	0.118098807	0.000	±	0.169	0.000	±	0.187
OP132HTR02	HW	07/26/13	91.800	1.480	1.77	120	9	106.40	6/13/2000	0.1976	0.073462	0.083376	0.136816488	0.192	±	0.219	0.353	±	0.404
OP132HTR03	HW	07/26/13	91.800	1.480	1.67	120	9	106.40	6/13/2000	0.1976	0.04813	0.082084	0.136816488	0.205	±	0.351	0.260	±	0.444
OP132HTR04	HW	07/23/13	92.54	1.49	1.49	120	9	106.40	6/13/2000	0.1991	0	0.079235	0.136221212	0.000	±	0.396	0.000	±	0.489
OP133HTR02	HW	10/28/13	85.60	1.45	1.34	130	9	106.40	6/13/2000	0.1868	-0.0284	0.078455	0.137280929	-0.260	±	0.719	-0.181	±	0.501
OP133HTR03	HW	10/03/13	84.69	1.54	1.61	120	9	106.40	6/13/2000	0.1838	0.019057	0.088217	0.14986738	0.139	±	0.642	0.116	±	0.538
OP133HTR04	HW	10/14/13	86.31	1.94	1.96	130	9	106.40	6/13/2000	0.1869	0.005357	0.092787	0.158063067	0.029	±	0.506	0.031	±	0.540
OP133HTR05	HW	10/11/13	97.07	4.65	4.89	200	9	106.40	6/13/2000	0.2046	0.058712	0.106858	0.177141536	0.979	±	1.787	0.294	±	0.537
OP134HTR02	HW	01/24/14	86.40	1.46	1.96	120	9	106.40	6/13/2000	0.1911	0.13095	0.088427	0.140533578	0.269	±	0.186	0.516	±	0.356
OP141HTR02	HW	04/29/14	86.21	1.49	1.48	130	9	106.40	6/13/2000	0.1934	-0.00259	0.078222	0.134486445	-0.007	±	0.203	-0.007	±	0.214
OP141HTR03	HW	04/29/14	92.45	4.45	4.69	190	9	106.40	6/13/2000	0.2009	0.059787	0.109275	0.181211441	0.177	±	0.324	0.231	±	0.424
OP142HTR02	HW	07/30/14	90.83	4.58	4.28	200	9	106.40	6/13/2000	0.1997	-0.07518	0.105484	0.180103662	-0.308	±	0.435	-0.361	±	0.510
OP142HTR02	HW	07/30/14	90.83	4.58	4.90	200	9	106.40	6/13/2000	0.1997	0.080187	0.109112	0.180103662	0.329	±	0.450	0.385	±	0.527
OP142HTR03	HW	07/30/14	90.83	4.58	4.32	200	9	106.40	6/13/2000	0.1997	-0.06515	0.105721	0.180103662	-0.347	±	0.565	-0.377	±	0.613
OP142HTR04	HW	07/30/14	90.83	4.58	4.42	200	9	106.40	6/13/2000	0.1997	-0.04009	0.106314	0.180103662	-0.310	±	0.822	-0.247	±	0.657
OP143HTR02	HW	09/25/14	88.12	4.34	4.64	200	9	106.40	6/13/2000	0.1957	0.076714	0.108369	0.179001211	0.630	±	0.894	0.489	±	0.695
OP143HTR03	HW	09/25/14	88.12	4.34	4.62	200	9	106.40	6/13/2000	0.1957	0.071599	0.108248	0.179001211	0.672	±	1.021	0.416	±	0.632
OP143HTR03	HW	09/25/14	88.12	4.34	4.71	200	9	106.40	6/13/2000	0.1957	0.094613	0.10879	0.179001211	0.888	±	1.029	0.550	±	0.637
OP143HTR04	HW	10/24/14	88.92	4.10	4.47	200	9	106.40	6/13/2000	0.1990	0.093036	0.104101	0.171176334	0.686	±	0.774	0.503	±	0.567
OP143HTR05	HW	10/20/14	82.61	1.40	1.61	120	9	106.40	6/13/2000	0.1905	0.055186	0.083239	0.138205929	0.426	±	0.646	0.276	±	0.419
OP144HTR02	HW	01/22/15	86.00	4.43	4.52	200	9	106.40	6/13/2000	0.1941	0.021059	0.109086	0.182398228	0.112	±	0.578	0.092	±	0.479
OP144HTR03	HW	01/19/15	79.45	1.43	1.39	130	9	106.40	6/13/2000	0.1856	-0.01079	0.07945	0.137445934	-0.034	±	0.253	-0.034	±	0.251

Table B6 – EML HTO Analysis – Idaho Falls 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121ITR02	IF	4/3/2012	81.66	1.39	1.37	130	9	85.07	6/13/2000	0.2040	-0.00491	0.071507	0.123353208	-0.017	±	0.254	-0.017	±	0.249
OP121ITR03	IF	4/3/2012	81.66	1.39	1.58	130	9	85.07	6/13/2000	0.2040	0.046622	0.074177	0.123353208	0.166	±	0.265	0.203	±	0.324
OP121ITR04	IF	4/17/2012	89.79	4.37	5.03	200	9	85.07	6/13/2000	0.2175	0.151857	0.099763	0.161607873	0.828	±	0.556	0.721	±	0.484
OP121ITR04	IF	4/26/2012	89.86	4.58	4.81	200	9	85.07	6/13/2000	0.2175	0.052933	0.099735	0.165412857	0.289	±	0.545	0.251	±	0.475
OP122ITR02	IF	7/25/2012	80.37	1.54	1.55	120	9	85.07	6/13/2000	0.2038	0.002455	0.078803	0.135167048	0.012	±	0.382	0.012	±	0.399
OP122ITR03	IF	7/25/2012	80.37	1.54	1.49	130	9	85.07	6/13/2000	0.2038	-0.01228	0.074973	0.129655292	-0.061	±	0.374	-0.072	±	0.441
OP122ITR04	IF	7/25/2012	80.37	1.54	1.61	130	9	85.07	6/13/2000	0.2038	0.017188	0.076443	0.129655292	0.094	±	0.420	0.121	±	0.540
OP123ITR02	IF	9/19/2012	80.12	1.71	1.62	120	9	85.07	6/13/2000	0.2045	-0.02203	0.081536	0.141665843	-0.206	±	0.762	-0.232	±	0.860
OP123ITR03	IF	9/19/2012	85.64	4.5	4.38	200	9	85.07	6/13/2000	0.2116	-0.02838	0.099666	0.168515943	-0.248	±	0.873	-0.299	±	1.051
OP123ITR04	IF	9/19/2012	85.64	4.5	4.43	200	9	85.07	6/13/2000	0.2116	-0.01655	0.099946	0.168515943	-0.131	±	0.789	-0.145	±	0.877
OP123ITR05	IF	9/19/2012	85.64	4.5	4.64	200	9	85.07	6/13/2000	0.2116	0.03311	0.101115	0.168515943	0.287	±	0.877	0.290	±	0.888
OP123ITR06	IF	11/5/2012	84.31	4.5	4.49	200	9	85.07	6/13/2000	0.2097	-0.00239	0.101216	0.170085881	-0.015	±	0.656	-0.019	±	0.818
OP123ITR07	IF	11/5/2012	84.31	4.5	4.69	200	9	85.07	6/13/2000	0.2097	0.045353	0.102335	0.170085881	0.369	±	0.835	0.335	±	0.757
OP124ITR02	IF	01/18/13	82.42	4.37	4.49	200	9	85.07	6/13/2000	0.2074	0.028957	0.10158	0.169491846	0.147	±	0.516	0.154	±	0.540
OP124ITR03	IF	01/18/13	82.42	4.37	4.55	200	9	85.07	6/13/2000	0.2074	0.043436	0.101924	0.169491846	0.217	±	0.511	0.234	±	0.551
OP124ITR04	IF	01/18/13	82.42	4.37	4.65	200	9	85.07	6/13/2000	0.2074	0.067567	0.102493	0.169491846	0.343	±	0.522	0.316	±	0.481
OP131ITR02	IF	04/30/13	78.020	1.310	1.65	110	9	85.07	6/13/2000	0.2071	0.082175	0.079294	0.128864087	0.224	±	0.219	0.250	±	0.243
OP131ITR03	IF	04/30/13	78.020	1.310	1.45	120	9	85.07	6/13/2000	0.2071	0.033837	0.073309	0.123135266	0.123	±	0.267	0.133	±	0.289
OP132ITR02	IF	07/26/13	91.800	1.480	1.65	130	9	106.40	6/13/2000	0.1976	0.043064	0.078613	0.131233405	0.158	±	0.290	0.187	±	0.342
OP132ITR03	IF	07/26/13	98.930	4.410	4.66	200	9	106.40	6/13/2000	0.2068	0.060515	0.103096	0.170779195	0.347	±	0.593	0.440	±	0.752
OP132ITR04	IF	07/23/13	92.54	1.49	1.83	110	9	106.40	6/13/2000	0.1991	0.085476	0.087351	0.142542096	0.584	±	0.602	0.676	±	0.698
OP133ITR02	IF	10/28/13	85.60	1.45	1.35	130	9	106.40	6/13/2000	0.1868	-0.02572	0.078596	0.137280929	-0.209	±	0.641	-0.261	±	0.800
OP133ITR03	IF	10/03/13	84.69	1.54	1.73	120	9	106.40	6/13/2000	0.1838	0.051726	0.089882	0.14986738	0.399	±	0.695	0.498	±	0.868
OP133ITR04	IF	10/14/13	86.31	1.94	1.74	120	9	106.40	6/13/2000	0.1869	-0.05357	0.093812	0.164754566	-0.517	±	0.909	-0.487	±	0.856
OP133ITR05	IF	10/11/13	97.07	4.65	4.63	200	9	106.40	6/13/2000	0.2046	-0.00489	0.105392	0.177141536	-0.051	±	1.096	-0.045	±	0.980
OP133ITR06	IF	10/14/13	86.31	1.94	2.04	120	9	106.40	6/13/2000	0.1869	0.026785	0.097561	0.164754566	0.180	±	0.657	0.249	±	0.908
OP134ITR02	IF	02/11/14	85.14	1.65	1.67	110	9	106.40	6/13/2000	0.1884	0.005314	0.092323	0.158194375	0.027	±	0.467	0.028	±	0.494
OP134ITR02	IF	01/24/14	86.40	1.46	1.59	130	9	106.40	6/13/2000	0.1911	0.034047	0.080231	0.134797362	0.172	±	0.406	0.182	±	0.430
OP134ITR02	IF	01/24/14	86.40	1.46	2.10	120	9	106.40	6/13/2000	0.1911	0.167616	0.090219	0.140533578	0.847	±	0.471	0.896	±	0.498
OP134ITR03	IF	02/03/14	85.61	1.57	1.68	130	9	106.40	6/13/2000	0.1894	0.029073	0.083578	0.140858433	0.131	±	0.378	0.129	±	0.370
OP134ITR03	IF	01/24/14	86.40	1.46	1.55	130	9	106.40	6/13/2000	0.1911	0.023571	0.079703	0.134797362	0.106	±	0.360	0.104	±	0.353
OP134ITR04	IF	02/03/14	91.60	4.60	4.49	200	9	106.40	6/13/2000	0.1960	-0.02808	0.108856	0.183888731	-0.084	±	0.327	-0.074	±	0.286
OP141ITR02	IF	04/29/14	86.21	1.49	1.29	130	9	106.40	6/13/2000	0.1934	-0.05175	0.075679	0.134486445	-0.179	±	0.263	-0.193	±	0.283
OP141ITR03	IF	04/29/14	92.45	4.45	4.87	200	9	106.40	6/13/2000	0.2009	0.104627	0.107552	0.176535376	0.399	±	0.414	0.439	±	0.456
OP142ITR02	IF	07/30/14	90.83	4.58	4.70	200	9	106.40	6/13/2000	0.1997	0.03007	0.107955	0.180103662	0.127	±	0.457	0.163	±	0.584
OP142ITR03	IF	07/31/14	82.42	1.20	1.42	130	9	106.40	6/13/2000	0.1881	0.058534	0.075542	0.12466703	0.292	±	0.380	0.430	±	0.559
OP142ITR04	IF	07/30/14	90.83	4.58	4.70	200	9	106.40	6/13/2000	0.1997	0.03007	0.107955	0.180103662	0.234	±	0.839	0.221	±	0.794
OP143ITR02	IF	09/29/14	90.07	4.63	4.42	200	9	106.40	6/13/2000	0.1997	-0.05262	0.106611	0.181069367	-0.499	±	1.014	-0.515	±	1.046
OP143ITR02	IF	09/29/14	90.07	4.63	4.32	200	9	106.40	6/13/2000	0.1997	-0.07768	0.10602	0.181069367	-0.737	±	1.011	-0.760	±	1.043
OP143ITR03	IF	09/25/14	88.12	4.34	4.33	200	9	106.40	6/13/2000	0.1957	-0.00256	0.106482	0.179001211	-0.023	±	0.940	-0.027	±	1.111
OP143ITR04	IF	10/24/14	88.92	4.10	4.41	200	9	106.40	6/13/2000	0.1990	0.077949	0.103736	0.171176334	0.831	±	1.112	0.865	±	1.157
OP143ITR05	IF	10/20/14	82.61	1.40	1.54	130	9	106.40	6/13/2000	0.1905	0.03679	0.079038	0.132560273	0.243	±	0.523	0.357	±	0.768
OP143ITR06	IF	10/20/14	82.61	1.40	1.63	130	9	106.40	6/13/2000	0.1905	0.060441	0.080239	0.132560273	0.562	±	0.750	0.502	±	0.670
OP144ITR02	IF	01/22/15	86.00	4.43	4.62	200	9	106.40	6/13/2000	0.1941	0.048134	0.109725	0.182398228	0.251	±	0.573	0.298	±	0.681
OP144ITR03	IF	01/19/15	79.45	1.43	1.67	130	9	106.40	6/13/2000	0.1856	0.064732	0.083301	0.137445934	0.235	±	0.305	0.266	±	0.344
OP144ITR04	IF	01/19/15	79.45	1.43	1.54	130	9	106.40	6/13/2000	0.1856	0.029669	0.081535	0.137445934	0.115	±	0.317	0.127	±	0.350

Table B7 – EML HTO Analysis – Monteview 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121MTR02	ML	4/3/2012	81.66	1.39	1.47	130	9	85.07	6/13/2000	0.2040	0.01963	0.072791	0.123353208	0.055	±	0.206	0.050	±	0.187
OP121MTR03	ML	4/3/2012	81.66	1.39	1.51	130	9	85.07	6/13/2000	0.2040	0.029445	0.073298	0.123353208	0.093	±	0.231	0.085	±	0.212
OP121MTR04	ML	4/17/2012	89.79	4.37	4.52	190	9	85.07	6/13/2000	0.2175	0.034513	0.099539	0.165889275	0.194	±	0.560	0.134	±	0.386
OP122MTR02	ML	7/23/2012	87.29	4.59	4.64	200	9	85.07	6/13/2000	0.2138	0.011706	0.100591	0.168452305	0.050	±	0.434	0.050	±	0.426
OP122MTR03	ML	7/25/2012	80.37	1.54	1.75	130	9	85.07	6/13/2000	0.2038	0.051563	0.078123	0.129655292	0.244	±	0.371	0.278	±	0.423
OP122MTR04	ML	7/25/2012	80.37	1.54	1.52	130	9	85.07	6/13/2000	0.2038	-0.00491	0.075343	0.129655292	-0.035	±	0.534	-0.028	±	0.436
OP122MTR05	ML	7/23/2012	87.29	4.59	4.58	200	9	85.07	6/13/2000	0.2138	-0.00234	0.100263	0.168452305	-0.015	±	0.626	-0.014	±	0.618
OP123MTR02	ML	9/19/2012	80.12	1.71	1.86	120	9	85.07	6/13/2000	0.2045	0.03671	0.084423	0.141665843	0.355	±	0.817	0.234	±	0.539
OP123MTR03	ML	9/19/2012	85.64	4.5	4.73	200	9	85.07	6/13/2000	0.2116	0.054394	0.101611	0.168515943	0.544	±	1.018	0.347	±	0.650
OP123MTR03	ML	9/19/2012	85.64	4.5	4.42	200	9	85.07	6/13/2000	0.2116	-0.01892	0.09989	0.168515943	-0.189	±	0.999	-0.121	±	0.637
OP123MTR04	ML	9/19/2012	85.64	4.5	4.41	200	9	85.07	6/13/2000	0.2116	-0.02128	0.099834	0.168515943	-0.177	±	0.832	-0.130	±	0.609
OP123MTR05	ML	9/19/2012	85.64	4.5	4.61	200	9	85.07	6/13/2000	0.2116	0.026015	0.100948	0.168515943	0.227	±	0.882	0.151	±	0.587
OP123MTR06	ML	11/5/2012	84.31	4.5	4.61	200	9	85.07	6/13/2000	0.2097	0.026257	0.101889	0.170085881	0.200	±	0.778	0.142	±	0.551
OP123MTR07	ML	11/5/2012	84.31	4.5	4.66	200	9	85.07	6/13/2000	0.2097	0.038192	0.102168	0.170085881	0.259	±	0.693	0.191	±	0.512
OP124MTR02	ML	01/18/13	82.42	4.37	4.57	200	9	85.07	6/13/2000	0.2074	0.048262	0.102038	0.169491846	0.232	±	0.492	0.212	±	0.448
OP124MTR03	ML	01/18/13	82.42	4.37	4.47	200	9	85.07	6/13/2000	0.2074	0.024131	0.101465	0.169491846	0.111	±	0.468	0.087	±	0.365
OP131MTR02	ML	04/30/13	78.020	1.310	1.61	100	9	85.07	6/13/2000	0.2071	0.072507	0.0826	0.135458607	0.186	±	0.213	0.205	±	0.235
OP132MTR02	ML	07/26/13	91.800	1.480	1.68	120	9	106.40	6/13/2000	0.1976	0.050663	0.082214	0.136816488	0.189	±	0.308	0.214	±	0.349
OP132MTR03	ML	07/26/13	98.930	4.410	4.39	200	9	106.40	6/13/2000	0.2068	-0.00484	0.10155	0.170779195	-0.032	±	0.674	-0.026	±	0.548
OP132MTR04	ML	07/23/13	92.54	1.49	1.69	120	9	106.40	6/13/2000	0.1991	0.05028	0.08185	0.136221212	0.294	±	0.481	0.291	±	0.475
OP132MTR05	ML	07/23/13	92.54	1.49	1.76	130	9	106.40	6/13/2000	0.1991	0.067878	0.0795	0.130663112	0.537	±	0.634	0.392	±	0.463
OP133MTR02	ML	10/28/13	85.60	1.45	1.58	130	9	106.40	6/13/2000	0.1868	0.035907	0.081764	0.137280929	0.339	±	0.772	0.229	±	0.522
OP133MTR02	ML	10/28/13	85.60	1.45	1.44	130	9	106.40	6/13/2000	0.1868	-0.00161	0.07985	0.137280929	-0.015	±	0.753	-0.010	±	0.509
OP133MTR03	ML	10/03/13	84.69	1.54	1.78	120	9	106.40	6/13/2000	0.1838	0.065339	0.090566	0.14986738	0.614	±	0.856	0.417	±	0.581
OP133MTR04	ML	10/14/13	86.31	1.94	1.76	130	9	106.40	6/13/2000	0.1869	-0.04821	0.090376	0.158063067	-0.369	±	0.694	-0.280	±	0.527
OP133MTR05	ML	10/11/13	97.07	4.65	4.92	200	9	106.40	6/13/2000	0.2046	0.066052	0.107026	0.177141536	0.631	±	1.027	0.384	±	0.625
OP133MTR06	ML	10/14/13	86.31	1.94	1.61	130	9	106.40	6/13/2000	0.1869	-0.08839	0.088526	0.158063067	-0.929	±	0.939	-0.443	±	0.447
OP133MTR07	ML	10/14/13	86.31	1.94	1.85	130	9	106.40	6/13/2000	0.1869	-0.02411	0.091469	0.158063067	-0.206	±	0.783	-0.121	±	0.458
OP134MTR02	ML	01/24/14	86.40	1.46	1.40	130	9	106.40	6/13/2000	0.1911	-0.01571	0.077692	0.134797362	-0.077	±	0.379	-0.069	±	0.341
OP134MTR03	ML	02/03/14	91.60	4.60	4.41	200	9	106.40	6/13/2000	0.1960	-0.04851	0.108376	0.183888731	-0.167	±	0.373	-0.175	±	0.391
OP134MTR04	ML	02/03/14	91.60	4.60	4.82	200	9	106.40	6/13/2000	0.1960	0.056167	0.110815	0.183888731	0.147	±	0.290	0.152	±	0.301
OP141MTR02	ML	04/29/14	86.21	1.49	1.40	130	9	106.40	6/13/2000	0.1934	-0.02329	0.077161	0.134486445	-0.069	±	0.230	-0.064	±	0.211
OP141MTR03	ML	04/29/14	92.45	4.45	4.43	200	9	106.40	6/13/2000	0.2009	-0.00498	0.104983	0.176535376	-0.018	±	0.389	-0.019	±	0.406
OP142MTR02	ML	07/30/14	90.83	4.58	4.60	200	9	106.40	6/13/2000	0.1997	0.005012	0.107372	0.180103662	0.022	±	0.474	0.021	±	0.454
OP142MTR03	ML	07/30/14	90.83	4.58	4.72	200	9	106.40	6/13/2000	0.1997	0.035082	0.108071	0.180103662	0.196	±	0.603	0.189	±	0.583
OP142MTR04	ML	07/30/14	90.83	4.58	4.40	200	9	106.40	6/13/2000	0.1997	-0.04511	0.106196	0.180103662	-0.336	±	0.793	-0.278	±	0.656
OP143MTR02	ML	09/29/14	90.07	4.63	4.56	200	9	106.40	6/13/2000	0.1997	-0.01754	0.107432	0.181069367	-0.175	±	1.073	-0.112	±	0.685
OP143MTR03	ML	09/25/14	88.12	4.34	4.58	200	9	106.40	6/13/2000	0.1957	0.061371	0.108006	0.179001211	0.538	±	0.950	0.374	±	0.661
OP143MTR04	ML	10/24/14	88.92	4.10	4.52	200	9	106.40	6/13/2000	0.1990	0.105608	0.104404	0.171176334	1.106	±	1.104	0.614	±	0.613
OP143MTR04	ML	10/24/14	88.92	4.10	4.59	200	9	106.40	6/13/2000	0.1990	0.12321	0.104827	0.171176334	1.290	±	1.113	0.716	±	0.618
OP143MTR05	ML	10/20/14	82.61	1.40	1.48	130	9	106.40	6/13/2000	0.1905	0.021023	0.078228	0.132560273	0.172	±	0.642	0.114	±	0.423
OP143MTR06	ML	10/24/14	88.91	4.10	4.66	200	9	106.40	6/13/2000	0.1990	0.140828	0.105261	0.171196518	1.016	±	0.772	0.705	±	0.536
OP143MTR07	ML	10/20/14	82.61	1.40	1.50	130	9	106.40	6/13/2000	0.1905	0.026279	0.078499	0.132560273	0.237	±	0.709	0.132	±	0.393
OP144MTR02	ML	01/22/15	86.00	4.43	4.63	200	9	106.40	6/13/2000	0.1941	0.050713	0.109785	0.182398228	0.254	±	0.551	0.222	±	0.482
OP144MTR02	ML	01/22/15	86.00	4.43	4.58	200	9	106.40	6/13/2000	0.1941	0.03782	0.109482	0.182398228	0.189	±	0.549	0.166	±	0.481
OP144MTR03	ML	01/22/15	86.00	4.43	4.69	200	9	106.40	6/13/2000	0.1941	0.066184	0.110148	0.182398228	0.199	±	0.333	0.238	±	0.398
OP144MTR04	ML	01/19/15	79.45	1.43	1.51	130	9	106.40	6/13/2000	0.1856	0.021577	0.081123	0.137445934	0.082	±	0.310	0.058	±	0.220

Table B8 – EML HTO Analysis – Mud Lake 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121VTR02	MV	4/3/2012	81.66	1.39	1.54	130	9	85.07	6/13/2000	0.2040	0.036807	0.073676	0.123353208	0.105	±	0.212	0.095	±	0.190
OP121VTR03	MV	4/3/2012	81.66	1.39	1.51	130	9	85.07	6/13/2000	0.2040	0.029445	0.073298	0.123353208	0.086	±	0.215	0.085	±	0.212
OP121VTR04	MV	4/17/2012	89.79	4.37	4.79	200	9	85.07	6/13/2000	0.2175	0.096636	0.098481	0.161607873	0.444	±	0.457	0.374	±	0.385
OP122VTR02	MV	7/25/2012	80.37	1.54	1.68	130	9	85.07	6/13/2000	0.2038	0.034376	0.077287	0.129655292	0.149	±	0.335	0.145	±	0.328
OP122VTR03	MV	7/25/2012	80.37	1.54	1.54	130	9	85.07	6/13/2000	0.2038	0	0.075589	0.129655292	0.000	±	0.388	0.000	±	0.408
OP122VTR04	MV	7/23/2012	87.29	4.59	5.07	200	9	85.07	6/13/2000	0.2138	0.112379	0.102907	0.168452305	0.703	±	0.652	0.693	±	0.642
OP123VTR02	MV	9/19/2012	80.12	1.71	1.82	130	9	85.07	6/13/2000	0.2045	0.02692	0.080656	0.135899821	0.269	±	0.806	0.172	±	0.515
OP123VTR03	MV	9/19/2012	85.64	4.5	4.79	200	9	85.07	6/13/2000	0.2116	0.068584	0.101941	0.168515943	0.770	±	1.150	0.437	±	0.653
OP123VTR04	MV	9/19/2012	85.64	4.5	4.66	200	9	85.07	6/13/2000	0.2116	0.03784	0.101225	0.168515943	0.321	±	0.859	0.231	±	0.618
OP123VTR05	MV	9/19/2012	85.64	4.5	4.74	200	9	85.07	6/13/2000	0.2116	0.056759	0.101666	0.168515943	0.450	±	0.809	0.330	±	0.593
OP123VTR06	MV	11/5/2012	84.31	4.5	4.51	200	9	85.07	6/13/2000	0.2097	0.002387	0.101328	0.170085881	0.016	±	0.665	0.012	±	0.507
OP123VTR07	MV	11/5/2012	84.31	4.5	4.62	200	9	85.07	6/13/2000	0.2097	0.028644	0.101945	0.170085881	0.229	±	0.817	0.143	±	0.511
OP124VTR02	MV	01/18/13	82.42	4.37	4.19	200	9	85.07	6/13/2000	0.2074	-0.04344	0.099846	0.169491846	-0.173	±	0.399	-0.204	±	0.470
OP124VTR03	MV	01/18/13	82.42	4.37	4.57	200	9	85.07	6/13/2000	0.2074	0.048262	0.102038	0.169491846	0.154	±	0.327	0.152	±	0.323
OP131VTR02	MV	04/30/13	78.020	1.310	1.08	100	9	85.07	6/13/2000	0.2071	-0.05559	0.074729	0.135458607	-0.118	±	0.159	-0.160	±	0.216
OP132VTR02	MV	07/26/13	91.800	1.480	1.54	120	9	106.40	6/13/2000	0.1976	0.015199	0.080372	0.136816488	0.051	±	0.268	0.073	±	0.386
OP132VTR03	MV	07/26/13	98.930	4.410	4.73	130	9	106.40	6/13/2000	0.2068	0.077459	0.128367	0.21280331	0.404	±	0.673	0.448	±	0.745
OP132VTR04	MV	07/23/13	92.54	1.49	1.86	120	9	106.40	6/13/2000	0.1991	0.093018	0.08401	0.136221212	0.584	±	0.533	0.574	±	0.524
OP133VTR02	MV	10/28/13	85.60	1.45	1.56	130	9	106.40	6/13/2000	0.1868	0.030548	0.081494	0.137280929	0.290	±	0.776	0.195	±	0.520
OP133VTR03	MV	10/03/13	84.69	1.54	1.82	130	9	106.40	6/13/2000	0.1838	0.076228	0.087536	0.143756183	0.745	±	0.862	0.486	±	0.562
OP133VTR04	MV	10/11/13	97.07	4.65	4.58	200	9	106.40	6/13/2000	0.2046	-0.01712	0.105108	0.177141536	-0.125	±	0.767	-0.100	±	0.611
OP133VTR05	MV	10/11/13	97.07	4.65	4.74	200	9	106.40	6/13/2000	0.2046	0.022017	0.106015	0.177141536	0.222	±	1.070	0.119	±	0.573
OP133VTR05	MV	10/11/13	97.07	4.65	4.38	200	9	106.40	6/13/2000	0.2046	-0.06605	0.103963	0.177141536	-0.666	±	1.053	-0.357	±	0.564
OP133VTR06	MV	10/11/13	97.07	4.65	4.73	200	9	106.40	6/13/2000	0.2046	0.019571	0.105958	0.177141536	0.170	±	0.921	0.098	±	0.531
OP134VTR02	MV	01/24/14	86.40	1.46	1.31	120	9	106.40	6/13/2000	0.1911	-0.03928	0.079582	0.140533578	-0.185	±	0.375	-0.172	±	0.350
OP134VTR03	MV	02/03/14	91.60	4.60	4.75	200	9	106.40	6/13/2000	0.1960	0.038296	0.110402	0.183888731	0.112	±	0.323	0.121	±	0.349
OP141VTR02	MV	04/29/14	92.45	4.45	4.63	200	9	106.40	6/13/2000	0.2009	0.04484	0.106158	0.176535376	0.128	±	0.303	0.122	±	0.291
OP141VTR03	MV	04/29/14	92.46	4.53	4.69	190	9	106.40	6/13/2000	0.2008	0.03989	0.10984	0.182946782	0.111	±	0.306	0.154	±	0.426
OP142VTR02	MV	07/31/14	82.42	1.20	1.45	130	9	106.40	6/13/2000	0.1881	0.066515	0.075974	0.12466703	0.274	±	0.316	0.282	±	0.324
OP142VTR03	MV	07/30/14	90.83	4.58	4.20	200	9	106.40	6/13/2000	0.1997	-0.09522	0.105006	0.180103662	-0.510	±	0.567	-0.514	±	0.571
OP142VTR04	MV	07/31/14	82.42	1.20	1.51	130	9	106.40	6/13/2000	0.1881	0.082479	0.076829	0.12466703	0.576	±	0.543	0.509	±	0.479
OP143VTR02	MV	09/29/14	90.070	4.63	4.42	200	9	106.40	6/13/2000	0.1997	-0.05262	0.106611	0.181069367	-0.540	±	1.097	-0.336	±	0.682
OP143VTR02	MV	09/29/14	90.07	4.63	4.41	200	9	106.40	6/13/2000	0.1997	-0.05513	0.106552	0.181069367	-0.566	±	1.097	-0.352	±	0.681
OP143VTR03	MV	09/29/14	90.07	4.63	4.47	200	9	106.40	6/13/2000	0.1997	-0.04009	0.106905	0.181069367	-0.354	±	0.944	-0.244	±	0.653
OP143VTR04	MV	10/24/14	88.92	4.10	4.44	200	9	106.40	6/13/2000	0.1990	0.085493	0.103919	0.171176334	0.862	±	1.055	0.497	±	0.608
OP143VTR05	MV	10/20/14	82.61	1.40	1.45	130	9	106.40	6/13/2000	0.1905	0.013139	0.077819	0.132560273	0.101	±	0.595	0.071	±	0.421
OP143VTR06	MV	10/24/14	88.91	4.10	4.26	200	9	106.40	6/13/2000	0.1990	0.040237	0.10283	0.171196518	0.319	±	0.816	0.201	±	0.516
OP144VTR02	MV	01/19/15	79.45	1.43	1.62	130	9	106.40	6/13/2000	0.1856	0.051246	0.082626	0.137445934	0.289	±	0.468	0.225	±	0.364
OP144VTR03	MV	01/22/15	86.00	4.43	4.45	200	9	106.40	6/13/2000	0.1941	0.004298	0.108689	0.182398228	0.013	±	0.320	0.014	±	0.343

Table B9 – EML HTO Analysis – Rest Area 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121RTR02	RA	4/3/2012	81.66	1.39	1.74	130	9	85.07	6/13/2000	0.2040	0.085882	0.076149	0.123353208	0.235	±	0.211	0.288	±	0.259
OP121RTR02	RA	4/26/2012	89.86	4.58	4.61	200	9	85.07	6/13/2000	0.2175	0.006904	0.098667	0.165412857	0.019	±	0.270	0.023	±	0.331
OP121RTR03	RA	4/3/2012	81.66	1.39	1.47	130	9	85.07	6/13/2000	0.2040	0.01963	0.072791	0.123353208	0.057	±	0.211	0.078	±	0.288
OP121RTR04	RA	4/17/2012	89.79	4.37	4.67	200	9	85.07	6/13/2000	0.2175	0.069026	0.097834	0.161607873	0.343	±	0.489	0.342	±	0.488
OP122RTR02	RA	7/25/2012	80.37	1.54	1.92	130	9	85.07	6/13/2000	0.2038	0.093305	0.080116	0.129655292	0.383	±	0.333	0.994	±	0.865
OP122RTR03	RA	8/3/2012	86.57	4.53	5.26	200	9	85.07	6/13/2000	0.2124	0.171992	0.104254	0.168428749	0.711	±	0.442	1.061	±	0.660
OP122RTR03	RA	7/25/2012	80.37	1.54	2.21	130	9	85.07	6/13/2000	0.2038	0.164512	0.083406	0.129655292	0.680	±	0.358	1.015	±	0.534
OP122RTR04	RA	7/23/2012	87.29	4.59	4.8	200	9	85.07	6/13/2000	0.2138	0.049166	0.101459	0.168452305	0.229	±	0.475	0.393	±	0.813
OP122RTR04	RA	7/23/2012	87.29	4.59	4.81	200	9	85.07	6/13/2000	0.2138	0.051507	0.101513	0.168452305	0.240	±	0.475	0.412	±	0.814
OP123RTR02	RA	9/19/2012	80.12	1.71	2.28	100	9	85.07	6/13/2000	0.2045	0.139497	0.09777	0.155765014	0.903	±	0.645	1.536	±	1.098
OP123RTR02	RA	9/19/2012	80.12	1.71	1.99	130	9	85.07	6/13/2000	0.2045	0.068525	0.082575	0.135899821	0.443	±	0.538	0.754	±	0.915
OP123RTR03	RA	9/19/2012	85.64	4.5	5.2	200	9	85.07	6/13/2000	0.2116	0.165548	0.104166	0.168515943	0.792	±	0.510	1.640	±	1.057
OP123RTR04	RA	11/8/2012	80.2	1.76	2.14	130	9	85.07	6/13/2000	0.2062	0.092248	0.084093	0.136686682	0.392	±	0.361	0.735	±	0.678
OP123RTR04	RA	11/8/2012	80.2	1.76	2	120	9	85.07	6/13/2000	0.2062	0.058262	0.085942	0.142483085	0.247	±	0.366	0.464	±	0.688
OP123RTR05	RA	11/8/2012	80.2	1.76	1.89	130	9	85.07	6/13/2000	0.2062	0.031558	0.081354	0.136686682	0.133	±	0.344	0.225	±	0.581
OP124RTR02	RA	01/18/13	82.42	4.37	4.30	200	9	85.07	6/13/2000	0.2074	-0.01689	0.100485	0.169491846	-0.075	±	0.445	-0.093	±	0.552
OP124RTR02	RA	01/18/13	82.42	4.37	4.68	200	9	85.07	6/13/2000	0.2074	0.074806	0.102664	0.169491846	0.331	±	0.457	0.410	±	0.566
OP124RTR03	RA	01/18/13	82.42	4.37	4.66	200	9	85.07	6/13/2000	0.2074	0.06998	0.10255	0.169491846	0.299	±	0.440	0.309	±	0.455
OP124RTR03	RA	01/18/13	82.42	4.37	4.67	200	9	85.07	6/13/2000	0.2074	0.072393	0.102607	0.169491846	0.309	±	0.440	0.320	±	0.456
OP131RTR02	RA	04/30/13	78.020	1.310	1.85	110	9	85.07	6/13/2000	0.2071	0.130513	0.081929	0.128864087	0.294	±	0.189	0.378	±	0.243
OP131RTR02	RA	04/30/13	78.020	1.310	1.58	120	9	85.07	6/13/2000	0.2071	0.065257	0.075015	0.123135266	0.147	±	0.170	0.189	±	0.219
OP131RTR03	RA	04/30/13	80.07	4.38	4.68	130	9	85.07	6/13/2000	0.2043	0.073484	0.129329	0.214626327	0.227	±	0.401	0.325	±	0.573
OP132RTR02	RA	07/26/13	91.800	1.480	1.69	130	9	106.40	6/13/2000	0.1976	0.053196	0.079113	0.131233405	0.139	±	0.208	0.222	±	0.332
OP132RTR03	RA	07/26/13	98.930	4.410	4.46	130	9	106.40	6/13/2000	0.2068	0.012103	0.126457	0.21280331	0.050	±	0.522	0.082	±	0.859
OP132RTR04	RA	08/05/13	96.91	4.57	4.53	200	9	106.40	6/13/2000	0.2023	-0.0099	0.105541	0.177619225	-0.045	±	0.478	-0.085	±	0.905
OP132RTR04	RA	08/05/13	96.91	4.57	4.84	200	9	106.40	6/13/2000	0.2023	0.066796	0.107324	0.177619225	0.303	±	0.488	0.572	±	0.923
OP133RTR02	RA	10/28/13	85.60	1.45	1.74	110	9	106.40	6/13/2000	0.1868	0.07878	0.091207	0.149769114	0.592	±	0.690	0.930	±	1.085
OP133RTR03	RA	10/03/13	84.69	1.54	2.00	130	9	106.40	6/13/2000	0.1838	0.125232	0.08985	0.143756183	0.701	±	0.512	1.479	±	1.081
OP133RTR03	RA	10/03/13	84.69	1.54	2.00	120	9	106.40	6/13/2000	0.1838	0.125232	0.093519	0.14986738	0.701	±	0.533	1.479	±	1.123
OP133RTR04	RA	10/11/13	97.07	4.65	5.30	200	9	106.40	6/13/2000	0.2046	0.159013	0.10913	0.177141536	0.909	±	0.637	1.449	±	1.015
OP133RTR05	RA	10/11/13	97.07	4.65	5.12	200	9	106.40	6/13/2000	0.2046	0.114979	0.108139	0.177141536	0.965	±	0.918	1.072	±	1.019
OP133RTR05	RA	10/11/13	97.07	4.65	4.67	200	9	106.40	6/13/2000	0.2046	0.004893	0.105619	0.177141536	0.041	±	0.886	0.046	±	0.984
OP134RTR02	RA	02/11/14	85.14	1.65	1.53	130	9	106.40	6/13/2000	0.1884	-0.03189	0.083115	0.145035132	-0.123	±	0.322	-0.164	±	0.427
OP134RTR02	RA	02/03/14	85.61	1.57	1.86	130	9	106.40	6/13/2000	0.1894	0.076646	0.085861	0.140858433	0.296	±	0.334	0.394	±	0.444
OP134RTR02	RA	01/24/14	86.40	1.46	4.85	120	9	106.40	6/13/2000	0.1911	0.887839	0.120113	0.140533578	3.431	±	0.668	4.559	±	0.888
OP134RTR03	RA	02/03/14	91.60	4.60	4.50	200	9	106.40	6/13/2000	0.1960	-0.02553	0.108916	0.183888731	-0.074	±	0.317	-0.104	±	0.446
OP134RTR04	RA	02/03/14	91.60	4.60	4.57	200	9	106.40	6/13/2000	0.1960	-0.00766	0.109334	0.183888731	-0.014	±	0.205	-0.018	±	0.264
OP141RTR02	RA	04/29/14	86.21	1.49	1.46	120	9	106.40	6/13/2000	0.1934	-0.00776	0.081142	0.140207181	-0.022	±	0.235	-0.022	±	0.235
OP141RTR02	RA	04/29/14	86.21	1.49	1.67	130	9	106.40	6/13/2000	0.1934	0.046576	0.080685	0.134486445	0.135	±	0.234	0.135	±	0.234
OP141RTR03	RA	04/29/14	86.21	1.49	1.46	130	9	106.40	6/13/2000	0.1934	-0.00776	0.077958	0.134486445	-0.025	±	0.252	-0.033	±	0.329
OP141RTR03	RA	04/29/14	86.21	1.49	1.52	100	9	106.40	6/13/2000	0.1934	0.007763	0.089786	0.15420025	0.025	±	0.290	0.033	±	0.379
OP142RTR02	RA	08/04/14	90.06	4.46	4.35	200	9	106.40	6/13/2000	0.1984	-0.02775	0.105903	0.178985077	-0.098	±	0.375	-0.154	±	0.589
OP142RTR02	RA	07/31/14	82.42	1.20	1.76	130	9	106.40	6/13/2000	0.1881	0.148995	0.080295	0.12466703	0.527	±	0.293	0.828	±	0.461
OP142RTR03	RA	07/30/14	90.83	4.58	4.87	200	9	106.40	6/13/2000	0.1997	0.072669	0.108939	0.180103662	0.267	±	0.402	0.523	±	0.788
OP142RTR04	RA	08/14/14	89.06	4.25	4.75	200	9	106.40	6/13/2000	0.1969	0.127125	0.107869	0.176158122	0.661	±	0.568	1.016	±	0.874
OP142RTR04	RA	07/31/14	82.42	1.20	1.67	130	9	106.40	6/13/2000	0.1881	0.125049	0.079064	0.12466703	0.650	±	0.421	1.000	±	0.648
OP143RTR02	RA	09/29/14	90.07	4.63	5.00	200	9	106.40	6/13/2000	0.1997	0.092718	0.109974	0.181069367	0.631	±	0.753	0.983	±	1.174
OP143RTR03	RA	09/25/14	88.12	4.34	4.90	200	9	106.40	6/13/2000	0.1957	0.143199	0.109926	0.179001211	1.072	±	0.836	1.555	±	1.213
OP143RTR04	RA	10/29/14	89.20	4.53	4.70	200	9	106.40	6/13/2000	0.1988	0.042789	0.108143	0.179934214	0.440	±	1.114	0.475	±	1.203
OP143RTR04	RA	10/24/14	88.92	4.10	4.95	200	9	106.40	6/13/2000	0.1990	0.213731	0.106977	0.171176334	2.199	±	1.143	2.373	±	1.233
OP143RTR05	RA	10/20/14	82.61	1.40	1.56	130	9	106.40	6/13/2000	0.1905	0.042046	0.079307	0.132560273	0.335	±	0.633	0.402	±	0.760
OP143RTR06	RA	10/24/14	88.92	4.10	4.57	200	9	106.40	6/13/2000	0.1990	0.118181	0.104707	0.171176334	0.781	±	0.700	0.945	±	0.848
OP144RTR02	RA	01/19/15	79.45	1.43	1.69	130	9	106.40	6/13/2000	0.1856	0.070127	0.083569	0.137445934	0.348	±	0.417	0.418	±	0.502
OP144RTR03	RA	01/19/15	79.45	1.43	1.55	130	9	106.40	6/13/2000	0.1856	0.032366	0.081673	0.137445934	0.113	±	0.285	0.122	±	0.309
OP144RTR03	RA	01/19/15	79.45	1.43	1.52	130	9	106.40	6/13/2000	0.1856	0.024275	0.08126	0.137445934	0.084	±	0.283	0.092	±	0.307
OP144RTR04	RA	01/19/15	79.45	1.43	1.50	130	9	106.40	6/13/2000	0.1856	0.01888	0.080985	0.137445934	0.073	±	0.313	0.078	±	0.333

Table B10 – EML HTO Analysis – Sand Dunes 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121STR02	SD	4/3/2012	81.66	1.39	1.43	130	9	85.07	6/13/2000	0.2040	0.009815	0.07228	0.123353208	0.028	±	0.205	0.027	±	0.197
OP121STR03	SD	4/17/2012	89.79	4.37	5.01	200	9	85.07	6/13/2000	0.2175	0.147255	0.099657	0.161607873	0.504	±	0.348	0.570	±	0.394
OP122STR02	SD	7/25/2012	80.37	1.54	1.75	130	9	85.07	6/13/2000	0.2038	0.051563	0.078123	0.129655292	0.195	±	0.296	0.231	±	0.351
OP122STR02	SD	7/25/2012	80.37	1.54	1.82	130	9	85.07	6/13/2000	0.2038	0.068751	0.07895	0.129655292	0.260	±	0.300	0.308	±	0.356
OP122STR03	SD	7/25/2012	80.37	1.54	1.82	130	9	85.07	6/13/2000	0.2038	0.068751	0.07895	0.129655292	0.302	±	0.350	0.397	±	0.460
OP123STR02	SD	9/19/2012	80.12	1.71	1.54	130	9	85.07	6/13/2000	0.2045	-0.0416	0.077391	0.135899821	-0.306	±	0.571	-0.265	±	0.495
OP123STR03	SD	9/19/2012	85.64	4.5	4.55	200	9	85.07	6/13/2000	0.2116	0.011825	0.100616	0.168515943	0.069	±	0.584	0.074	±	0.626
OP123STR04	SD	9/19/2012	85.64	4.5	4.68	200	9	85.07	6/13/2000	0.2116	0.042569	0.101336	0.168515943	0.254	±	0.607	0.248	±	0.590
OP123STR05	SD	11/8/2012	84.35	4.37	4.73	200	9	85.07	6/13/2000	0.2102	0.08571	0.10157	0.167224332	0.391	±	0.467	0.429	±	0.512
OP123STR05	SD	11/5/2012	84.31	4.5	4.94	200	9	85.07	6/13/2000	0.2097	0.105028	0.103718	0.170085881	0.479	±	0.478	0.526	±	0.524
OP124STR02	SD	01/18/13	82.42	4.37	4.46	190	9	85.07	6/13/2000	0.2074	0.021718	0.104042	0.173982114	0.091	±	0.434	0.087	±	0.415
OP124STR02	SD	01/18/13	82.42	4.37	4.47	200	9	85.07	6/13/2000	0.2074	0.024131	0.101465	0.169491846	0.101	±	0.423	0.096	±	0.405
OP124STR03	SD	01/18/13	82.42	4.37	4.60	200	9	85.07	6/13/2000	0.2074	0.055502	0.102209	0.169491846	0.208	±	0.384	0.175	±	0.323
OP124STR03	SD	01/18/13	82.42	4.37	4.74	200	9	85.07	6/13/2000	0.2074	0.089285	0.103003	0.169491846	0.334	±	0.388	0.282	±	0.327
OP131STR02	SD	04/30/13	78.020	1.310	1.44	130	9	85.07	6/13/2000	0.2071	0.03142	0.070305	0.118098807	0.080	±	0.180	0.090	±	0.202
OP132STR02	SD	07/26/13	91.800	1.480	1.80	130	9	106.40	6/13/2000	0.1976	0.081061	0.080474	0.131233405	0.251	±	0.252	0.390	±	0.391
OP132STR03	SD	07/26/13	98.930	4.410	4.61	200	9	106.40	6/13/2000	0.2068	0.048412	0.102811	0.170779195	0.175	±	0.373	0.280	±	0.596
OP133STR02	SD	10/28/13	85.60	1.45	1.55	130	9	106.40	6/13/2000	0.1868	0.027868	0.081358	0.137280929	0.187	±	0.546	0.178	±	0.519
OP133STR03	SD	10/03/13	84.69	1.54	1.83	110	9	106.40	6/13/2000	0.1838	0.078951	0.095303	0.156816914	0.449	±	0.546	0.481	±	0.585
OP133STR04	SD	10/30/13	94.94	4.46	4.54	200	9	106.40	6/13/2000	0.2009	0.019933	0.105711	0.176765058	0.137	±	0.725	0.116	±	0.615
OP133STR04	SD	10/30/13	94.94	4.46	4.68	200	9	106.40	6/14/2000	0.2008	0.054824	0.106546	0.176792343	0.376	±	0.733	0.319	±	0.621
OP133STR05	SD	10/14/13	86.31	1.94	1.80	130	9	106.40	6/13/2000	0.1869	-0.0375	0.090864	0.158063067	-0.338	±	0.819	-0.188	±	0.456
OP134STR02	SD	01/24/14	86.40	1.46	1.90	130	9	106.40	6/13/2000	0.1911	0.115236	0.08421	0.134797362	0.488	±	0.363	0.415	±	0.309
OP134STR03	SD	01/24/14	91.60	4.60	4.58	200	9	106.40	6/13/2000	0.1957	-0.00511	0.109563	0.18417277	-0.011	±	0.238	-0.014	±	0.297
OP141STR02	SD	04/29/14	86.21	1.49	1.31	130	9	106.40	6/13/2000	0.1934	-0.04658	0.07595	0.134486445	-0.122	±	0.199	-0.127	±	0.208
OP141STR03	SD	04/29/14	92.45	4.45	4.75	200	9	106.40	6/13/2000	0.2009	0.074734	0.106858	0.176535376	0.248	±	0.356	0.289	±	0.415
OP142STR02	SD	07/31/14	82.42	1.20	1.66	130	9	106.40	6/13/2000	0.1881	0.122388	0.078927	0.12466703	0.397	±	0.262	0.588	±	0.388
OP142STR03	SD	07/30/14	90.83	4.58	4.42	200	9	106.40	6/13/2000	0.1997	-0.04009	0.106314	0.180103662	-0.156	±	0.414	-0.247	±	0.657
OP143STR02	SD	09/29/14	90.07	4.63	4.46	200	9	106.40	6/13/2000	0.1997	-0.0426	0.106846	0.181069367	-0.322	±	0.809	-0.272	±	0.683
OP143STR03	SD	09/25/14	88.12	4.34	4.56	200	9	106.40	6/13/2000	0.1957	0.056257	0.107885	0.179001211	0.509	±	0.978	0.343	±	0.659
OP143STR04	SD	10/24/14	88.92	4.10	4.73	200	9	106.40	6/13/2000	0.1990	0.158413	0.105668	0.171176334	1.396	±	0.952	0.921	±	0.628
OP143STR05	SD	10/20/14	82.61	1.40	1.50	130	9	106.40	6/13/2000	0.1905	0.026279	0.078499	0.132560273	0.193	±	0.577	0.153	±	0.457
OP144STR02	SD	01/19/15	79.45	1.43	1.44	130	9	106.40	6/13/2000	0.1856	0.002697	0.080151	0.137445934	0.013	±	0.383	0.012	±	0.351
OP144STR03	SD	01/19/15	79.45	1.43	1.42	130	9	106.40	6/13/2000	0.1856	-0.0027	0.079871	0.137445934	-0.008	±	0.238	-0.009	±	0.252

Table B11 – EML HTO Analysis – Van Buren 2012-2014

Sample ID	Location ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
OP121BTR02	VB	4/3/2012	81.66	1.39	1.57	130	9	85.07	6/13/2000	0.2040	0.044168	0.074052	0.123353208	0.127	±	0.214	0.148	±	0.249
OP121BTR03	VB	4/3/2012	81.66	1.39	1.37	130	9	85.07	6/13/2000	0.2040	-0.00491	0.071507	0.123353208	-0.014	±	0.209	-0.020	±	0.298
OP121BTR04	VB	4/17/2012	89.79	4.37	4.98	200	9	85.07	6/13/2000	0.2175	0.140353	0.099497	0.161607873	0.828	±	0.599	0.696	±	0.503
OP121BTR04	VB	4/26/2012	89.86	4.58	5.05	200	9	85.07	6/13/2000	0.2175	0.108168	0.101002	0.165412857	0.638	±	0.603	0.536	±	0.506
OP122BTR02	VB	7/23/2012	87.29	4.59	4.75	200	9	85.07	6/13/2000	0.2138	0.03746	0.101189	0.168452305	0.135	±	0.364	0.399	±	1.080
OP122BTR03	VB	7/23/2012	87.29	4.59	5	200	9	85.07	6/13/2000	0.2138	0.09599	0.102534	0.168452305	0.387	±	0.417	0.609	±	0.656
OP122BTR04	VB	7/25/2012	80.37	1.54	2.07	130	9	85.07	6/13/2000	0.2038	0.130136	0.081834	0.129655292	0.505	±	0.326	1.041	±	0.670
OP123BTR02	VB	11/15/2012	81.23	1.97	2.49	120	9	85.07	6/13/2000	0.2086	0.124793	0.092532	0.14870915	0.954	±	0.720	1.374	±	1.037
OP123BTR02	VB	9/19/2012	80.12	1.71	2.5	130	9	85.07	6/13/2000	0.2045	0.193338	0.088082	0.135899821	1.478	±	0.704	2.128	±	1.014
OP123BTR03	VB	9/19/2012	80.12	1.71	2.17	120	9	85.07	6/13/2000	0.2045	0.112576	0.088013	0.141665843	0.488	±	0.387	1.115	±	0.886
OP123BTR04	VB	11/8/2012	80.2	1.76	2.06	120	9	85.07	6/13/2000	0.2062	0.072827	0.086625	0.142483085	0.375	±	0.449	0.581	±	0.695
OP123BTR05	VB	11/8/2012	84.35	4.37	4.75	200	9	85.07	6/13/2000	0.2102	0.090471	0.101681	0.167224332	0.460	±	0.521	0.645	±	0.730
OP124BTR02	VB	01/18/13	82.42	4.37	4.52	200	9	85.07	6/13/2000	0.2074	0.036197	0.101752	0.169491846	0.149	±	0.420	0.177	±	0.499
OP124BTR03	VB	01/18/13	82.42	4.37	4.55	200	9	85.07	6/13/2000	0.2074	0.043436	0.101924	0.169491846	0.177	±	0.417	0.192	±	0.451
OP131BTR02	VB	04/30/13	78.020	1.310	1.35	110	9	85.07	6/13/2000	0.2071	0.009668	0.075168	0.128864087	0.023	±	0.180	0.030	±	0.237
OP131BTR03	VB	04/30/13	78.020	1.310	1.54	110	9	85.07	6/13/2000	0.2071	0.055589	0.077807	0.128864087	0.189	±	0.266	0.276	±	0.388
OP132BTR02	VB	07/26/13	91.800	1.480	1.79	130	9	106.40	6/13/2000	0.1976	0.078528	0.080352	0.131233405	0.255	±	0.263	0.328	±	0.338
OP132BTR03	VB	07/26/13	91.800	1.480	1.77	120	9	106.40	6/13/2000	0.1976	0.073462	0.083376	0.136816488	0.310	±	0.354	0.325	±	0.371
OP132BTR04	VB	07/26/13	98.930	4.410	4.81	200	9	106.40	6/13/2000	0.2068	0.096824	0.103945	0.170779195	0.491	±	0.532	0.830	±	0.898
OP133BTR02	VB	10/28/13	85.60	1.45	1.83	120	9	106.40	6/13/2000	0.1868	0.102897	0.088549	0.143123926	0.766	±	0.668	1.048	±	0.914
OP133BTR03	VB	10/28/13	85.60	1.45	2.19	90	9	106.40	6/13/2000	0.1868	0.199363	0.107719	0.166346261	0.963	±	0.537	2.085	±	1.164
OP133BTR03	VB	11/05/13	86.98	2.09	2.79	130	9	106.40	6/13/2000	0.1886	0.185717	0.102807	0.162292473	0.897	±	0.512	1.942	±	1.109
OP133BTR04	VB	10/14/13	86.31	1.94	1.78	130	9	106.40	6/13/2000	0.1869	-0.04286	0.09062	0.158063067	-0.316	±	0.670	-0.392	±	0.831
OP133BTR05	VB	10/11/13	97.07	4.65	4.98	200	9	106.40	6/13/2000	0.2046	0.08073	0.107361	0.177141536	0.633	±	0.846	0.752	±	1.006
OP134BTR02	VB	01/24/14	86.40	1.46	1.78	130	9	106.40	6/13/2000	0.1911	0.083808	0.082692	0.134797362	0.298	±	0.297	0.387	±	0.386
OP141BTR02	VB	04/29/14	86.21	1.49	1.54	130	9	106.40	6/13/2000	0.1934	0.012938	0.079008	0.134486445	0.043	±	0.261	0.047	±	0.288
OP141BTR03	VB	04/29/14	92.45	4.45	4.60	200	9	106.40	6/13/2000	0.2009	0.037367	0.105983	0.176535376	0.109	±	0.308	0.158	±	0.448
OP142BTR02	VB	07/31/14	82.42	1.20	1.43	130	9	106.40	6/13/2000	0.1881	0.061194	0.075687	0.12466703	0.199	±	0.247	0.288	±	0.359
OP142BTR03	VB	08/04/14	90.06	4.46	4.95	200	9	106.40	6/13/2000	0.1984	0.123623	0.109449	0.178985077	0.477	±	0.427	0.790	±	0.708
OP142BTR03	VB	07/31/14	82.42	1.20	1.81	130	9	106.40	6/13/2000	0.1881	0.162298	0.08097	0.12466703	0.626	±	0.324	1.037	±	0.537
OP142BTR04	VB	07/30/14	90.83	4.58	4.99	200	9	106.40	6/13/2000	0.1997	0.102739	0.109629	0.180103662	0.566	±	0.609	0.821	±	0.884
OP143BTR02	VB	09/29/14	90.07	4.63	4.67	200	9	106.40	6/13/2000	0.1997	0.010024	0.108073	0.181069367	0.054	±	0.587	0.106	±	1.146
OP143BTR03	VB	09/25/14	88.12	4.63	4.76	200	9	106.40	6/13/2000	0.1951	0.033358	0.1112	0.185412873	0.331	±	1.104	0.370	±	1.236
OP143BTR04	VB	10/24/14	88.92	4.10	4.59	200	9	106.40	6/13/2000	0.1990	0.12321	0.104827	0.171176334	0.562	±	0.484	1.177	±	1.015
OP143BTR05	VB	10/24/14	88.92	4.10	4.49	200	9	106.40	6/13/2000	0.1990	0.098065	0.104222	0.171176334	0.848	±	0.909	0.784	±	0.841
OP144BTR02	VB	01/22/15	86.00	4.43	4.63	200	9	106.40	6/13/2000	0.1941	0.050713	0.109785	0.182398228	0.251	±	0.544	0.303	±	0.657
OP144BTR03	VB	01/22/15	86.00	4.43	4.70	200	9	106.40	6/13/2000	0.1941	0.068763	0.110208	0.182398228	0.226	±	0.364	0.272	±	0.437

Appendix C – Experimental Sampling Results taken from Microsoft Excel[23]

Table C1 – Experimental Sampling HTO Results

Sample ID	Analysis Date	STD CPM	BKG CPM	Sample CPM	Count Time	Sample Volume	STD dpm/ml	STD ref date	Efficiency	CONC pCi/ml	±2 StDev CONC	MDC	Atmospheric HTO		σ Atmospheric HTO	Atmospheric HTO with CE		σ Atmospheric HTO with CE
BKG1	2/22/2019	386.55	4.75	5.03	550	9	547.3333	9/1/1998	0.2452	0.057156	0.054441	0.08940713	0.065	±	0.062	0.871	±	0.831
BKG2	12/7/2018	386.55	4.75	5.16	495	9	547.3333	9/1/1998	0.2423	0.084692	0.058455	0.0954255	0.014	±	0.010	0.194	±	0.134
HTO1	11/16/2018	386.55	4.75	8.14	550	9	547.3333	9/1/1998	0.2415	0.702523	0.063451	0.09076656	0.788	±	0.078	10.897	±	1.076
HTO2	4/29/2019	386.55	4.75	6.7	495	9	547.3333	9/1/1998	0.2477	0.394029	0.061464	0.09334722	0.108	±	0.017	1.519	±	0.245

Table C2 – Experimental Sampling Data

Sample ID	Start	Stop	Sample Time (min)	MS Weight	C ave	RH% Ave	AH (g m^{-3})	Flow Rate (m^3 min^{-1})	Total mass	Mass Gain	Efficiency%	volume of air
BKG1	7/13/2018	8/10/2018	20171	386.23	21.72	39.90	7.62	0.0023	697.39	51.91	7.44%	45.7509659
BKG2	12/1/2017	3/23/2018	161280	387.54	23.12	22.13	4.58	0.0023	841.72	62.19	7.39%	367.5488388
HTO1	6/29/2018	7/13/2018	20160	379.33	22.45	38.91	7.76	0.0023	711.04	51.40	7.23%	45.83971658
HTO2	3/23/2018	5/11/2018	69180	378.88	23.69	18.12	3.86	0.0023	608.91	43.48	7.14%	157.956377

[23] Microsoft Corporation, One Microsoft Way, Redmond WA 98052-6399

Appendix D – Sampling Data vs AH

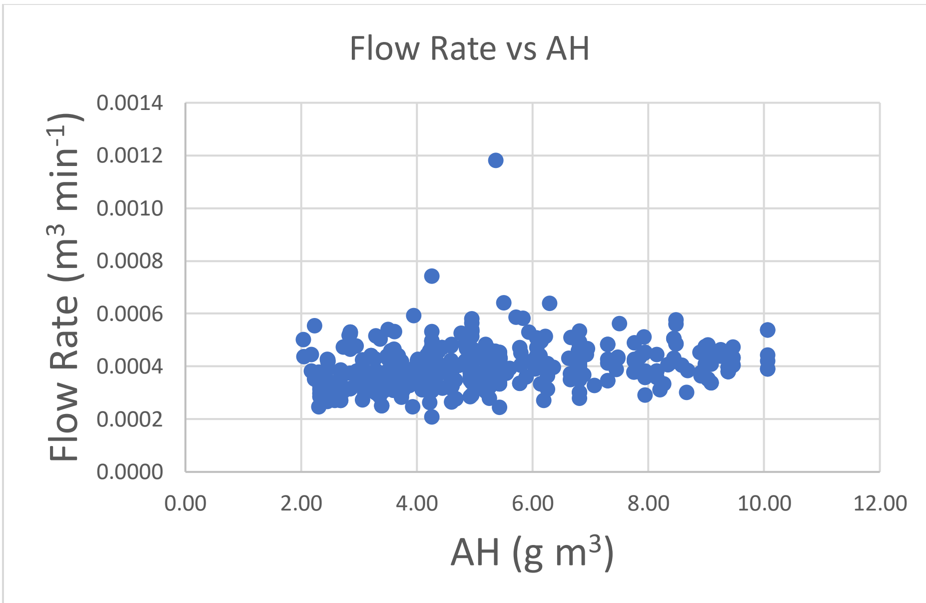

Figure D1. Flow Rate vs AH

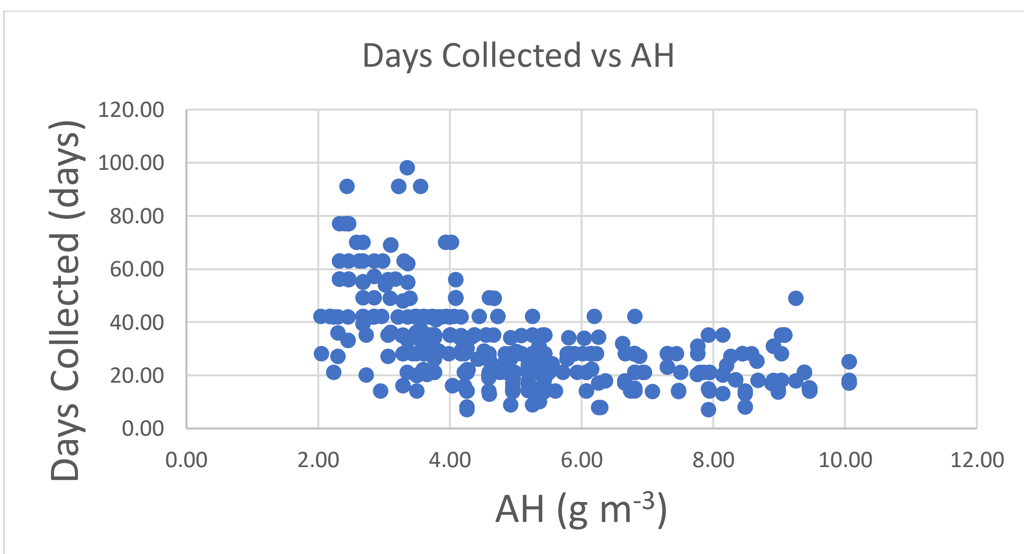

Figure D2. Days Collected vs AH

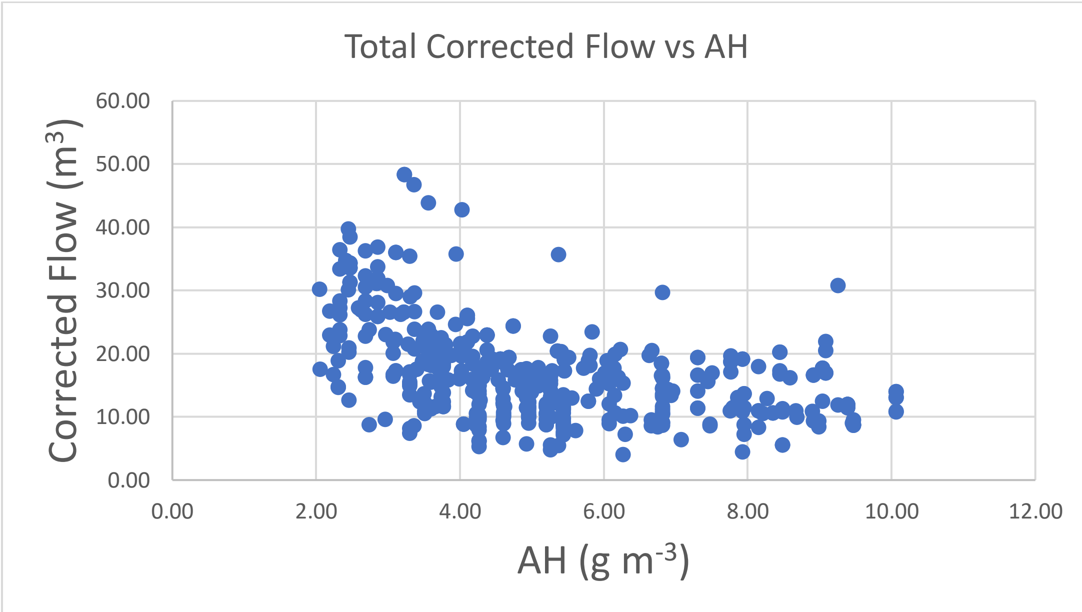

Figure D3. Corrected Flow vs Ah

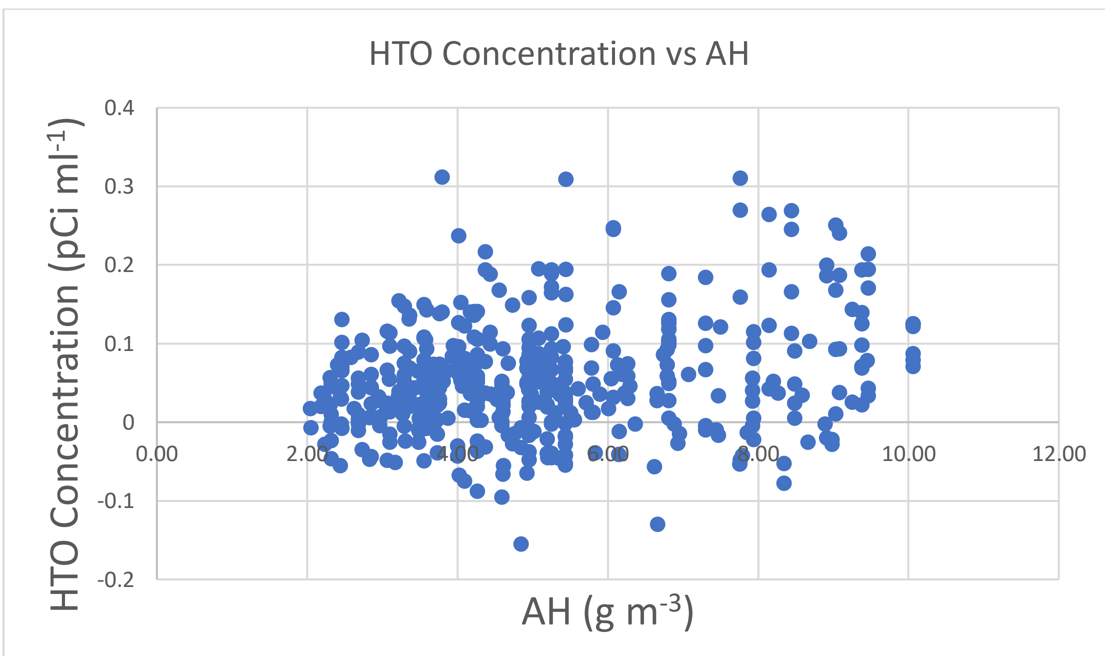

Figure D4. HTO Concentration vs AH

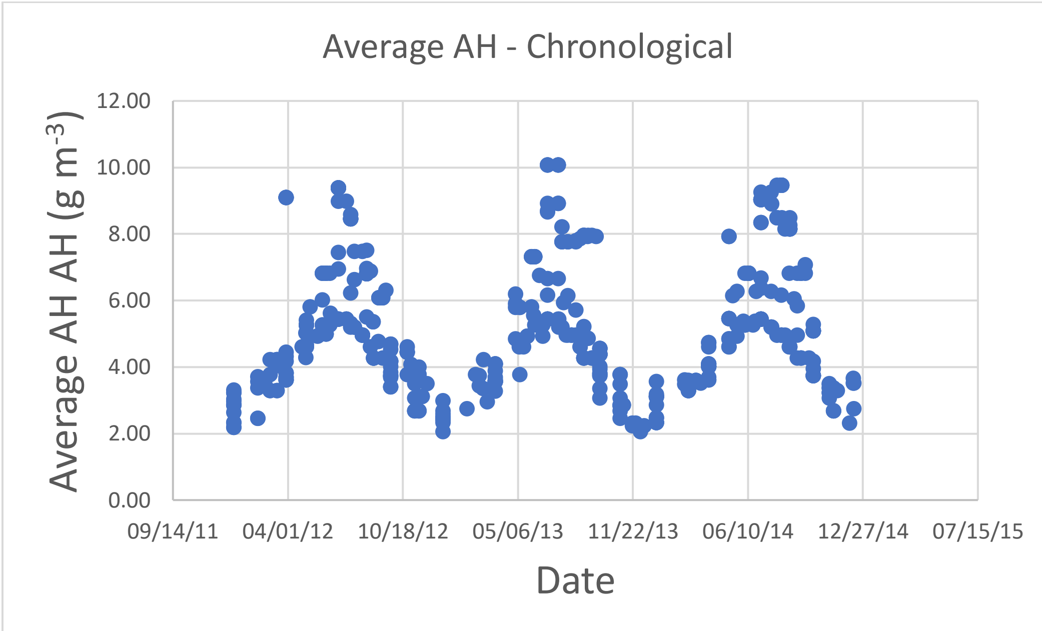

Figure D5. Chronological representation of Absolute Humidity