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317/319 Phytoremediation Site Monitoring Report – 2003 Growing Season

Energy Systems Division

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317/319 Phytoremediation Site Monitoring Report – 2003 Growing Season

by

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ANL 317/319 Phytoremediation Site
Monitoring Report –2003 Growing Season

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Abstract

In 1999, Argonne National Laboratory-East (ANL-E) designed and installed a series of engineered plantings consisting of a vegetative cover system and approximately 800 hybrid poplars and willows rooting at various predetermined depths. The plants were installed using various methods including Applied Natural Science's TreeWell® system. The goal of the installation was to protect downgradient surface and groundwater by hydraulic control of the contaminated plume by intercepting the contaminated groundwater with the tree roots, removing moisture from the upgradient soil area, reducing water infiltration, preventing soil erosion, degrading and/or transpiring the residual volatile organic compounds (VOCs), and removing tritium from the subsoil and groundwater.

This report presents the results of the monitoring activities conducted by Argonne's Energy Systems Division (ES) in the growing season of 2003. ES was tasked with the biomonitoring of the plantation to determine contaminant uptake and groundwater contact. VOCs were found in plant tissue both at the French Drain and the Hydraulic Control locations in varying concentrations, and tritium levels in transpirate was found to continue a trend of higher concentrations compared to the background in the ANL-E area.

Introduction

The 317/319 Area at Argonne National Laboratory-East (ANL-E) (approximately 2 hectares of surface) contains several release sites used in the past to dispose of solid and liquid waste from various laboratory activities. Because of these past activities, VOCs and tritium have been released in the groundwater at depths of approximately 6-9 m and have been detected in groundwater offsite. The U.S. Department of Energy (DOE) has funded ANL-E to deploy a phytoremediation system instead of the traditional technology of pump-and-treat on the basis of phytoremediation being more cost effective and better suited than mechanical extraction wells (currently removing groundwater as an interim measure) and an asphalt cap to achieve project goals.

As part of the deployment efforts, approximately 800 hybrid poplars and willows were planted in the summer of 1999 in and downgradient of the 317/319 Area at varying, predetermined depths as an engineered plantation. These trees have been planted so that root development targets the areas of soil and groundwater contamination, using methods that include the TreeWell® system patented by Applied Natural Sciences, Inc. In addition, a vegetative cover of herbaceous plants has been seeded among the trees to control soil erosion and minimize water infiltration. Appropriate control cells have been set up at the ANL-E greenhouse area (a clean area on site) to represent background conditions. Figure 1 depicts the remediation area: in the upgradient VOC source area (FD) hybrid willow trees were planted so that their roots

could freely explore the contaminated soil from the surface throughout the 9 m depth and take up excess water and entrained chemicals. A few poplars were also planted at the southernmost edge of the FD area with the same technique used in the hydraulic control area (see below) to contain the contaminated groundwater. In the downgradient area of groundwater contamination (hydraulic control area, or HC), hybrid poplars were planted using the TreeWell® technology so that their roots were isolated from clean surficial aquifers and forced to extend downwards to the deeper, contaminated groundwater.

The monitoring efforts had the purpose of determining and documenting the system's effectiveness in achieving the remediation objectives. Activities involved:

- Determining the uptake of the volatile contaminants in the plant tissue to document source reduction and contact with groundwater.
- Determining tritium concentration in tree transpirate and background rainfall samples.
- Installation of sap flow equipment and periodic download of data to determine sap flow rates (water consumption by trees).

Monitoring Protocols

VOC Contaminant Uptake

While it is known (Newman et al. 1997, and Gatliff et al. 1998) that trees such as poplars and willows are capable of taking up a number of organic compounds (including chlorinated solvents such as TCE, PCE, and carbon tetrachloride), there are varying hypotheses on the fate of those compounds in the rhizosphere and plant systems. These compounds have been shown to be degraded in the root zone (Nzengung et al. 2001), taken into the plant and vented through the bark (Ma and Burken 2003), and degraded in leaf tissue (Newman et al., 1999). Portions of these contaminants have shown to be vented out by the trees into the air via the transpirative flow or, during winter, by gas diffusion through the plant's air conducting tissue (Nietch et al. 1999, Vroblesky et al. 1999, and Davis et al. 1998).

Plant tissue was sampled to determine the presence of VOCs and their degradation intermediate trichloroacetic acid (TCAA). Finding VOCs in leaf and/or branch tissue above background levels would provide a clear indication that the trees are indeed taking up the contaminants from soil or groundwater and translocating it to the aboveground tissues. Finding TCAA in these tissues would provide a proof that at least a portion of the parent compounds is being degraded by the plant. In principle, by multiplying contaminant concentrations in the sap (ng/mL) by sap flow (L/day), a measure of contaminant removal by plant uptake can be obtained. In fact, this is still a very imprecise measurement because of unknown diffusion rates from the sap through cell walls into external air, and because it is still unknown how much of the total contaminant detected in tissue is in the freely moving sap and how much is adsorbed to the plant tissues, thus not flowing.

Samples of leaves, branches, and, new to the project this year, trunk cores (trunks were finally large enough to safely collect cores with reduced damage to the tree), were collected by

cutting leaves and branches with sharp scissors and directly placed into headspace vials, which were crimped airtight immediately after. Trunk cores of 0.5 cm diameter and approx 2.5 cm length were collected using an appositely designed core sampler. Gas chromatographic analysis was conducted within 24 hours. Samples were thermally equilibrated and decarboxylated (to convert TCAA to chloroform) at 90˚C for four hours before being analyzed via headspace according to the SOP developed during previous years. Control samples from plants growing in non-contaminated soil were also sampled and analyzed using the same methods. In addition to the compounds monitored previously, the gas chromatographic method was adjusted slightly to quantify also carbon tetrachloride (CT) and 1, 1, 1, trichloroethane (TCA). Detection limits were 3 ng/g for chloroform and TCE, 0.04 ng/g for PCE, 2.6 ng/g for CT, and 2 ng/g for TCA.

Samples were collected from 30 different trees (willows and poplars) at the 317 FD area, from 32 poplars at the hydraulic control area, plus willows and poplars at the greenhouse control plots, at various times during the 2003 summer and fall seasons, from June 2nd to November 5th. To determine background levels, additional samples were collected from trees of various species around the ANL campus (near Bldgs. 212, 213, 335, 362, 438, and wooded area near the 317 Area). In most sampling events, six samples were collected from each sampled tree, including three of branch tissue, and three of leaves growing on that branch. Core samples were usually collected in triplicate at three vertically positioned points at 57, 60, and 63 cm above ground level. Cores were collected only from selected trees that had an average diameter larger than 7-8 cm to minimize adverse impacts on the tree's health.

Tritium in Transpirate

Samples of transpirate were collected following the procedure established in the Year 2000 growing season on 14 test poplars and the greenhouse control poplars. Two rainwater samples (as background reference) were collected on July 24 from the French Drain collector and the 485 collector. All samples were forwarded to an off-site lab (Isotech Lab, Champaign, IL) that specializes in low-level tritium counting. Three sampling events took place during the test period: June 18, July 24, and September 10, 2003. Trees selected for tritium analyses were located in the 317 and 319 hydraulic control areas, both within and outside the Radiologically Controlled Area.

Sap Flow Measurements

In order to understand the effects of the plantings on the target groundwater and contaminants, ES also attempted at an estimation of consumption by trees through sap flow measurements. Such measurements had been conducted for the previous several years and the probes and datalogger had been transferred from SAIC to ANL for use. However, the use of the system this year has been conducted on a trial mode as the probes have reportedly reached their useful lifespan and cannot be serviced or recalibrated. Since the datalogger system is still in good working order and the automatic data logging would not represent a significant cost, the probes were installed on a tentative basis and judgment on the usability of the data was deferred to the time where all data were collected.

To assess water consumption via tree transpiration, thermal dissipation sap flow probes (TDPs) were installed on 6 poplar trees in the 317/319 HC Area and 4 willows at the 317 FD Area. Automatic measurements were logged continuously during June to November 2003. The TDP probe (Dynamax, Houston, TX) has two thermocouple needles inserted in the sapwood, the upper one containing a heating element under constant voltage. The probe needles measure the temperature difference between the heated needle and the sapwood ambient temperature below. The temperature difference under flow conditions and the maximum temperature difference at zero flow provide a direct conversion to sap velocity.

Cross-sectional areas of the stems (at the levels of the TDPs) were collected for the instrumented trees. The data collected from TDPs are related empirically to sap velocity (Granier, 1985) and the product of sap velocity and cross-sectional area yields the rate of sap flow (L day^{-1}).

Results

VOC Contaminant Uptake

Tables 1 to 4 summarize the tissue analysis results. Results are grouped by sample location (concentrations in trees at the FD area, Hydraulic Control area, and a collation of all the trees sampled for background reference). The full set of data collected is reported in Appendix 1.

Contrary of what was found in the past, starting from mid-summer our background controls showed consistently elevated concentrations primarily of TCE and CT (Table 1). While CT was not monitored during the last few years, TCE had proved in the past to be found inconsistently in the single digits ng/g on dry weight. TCE was consistently found in branches at higher concentrations in trees exposed to the contaminant in the soil, and rarely in the non-exposed controls. This year, TCE background concentrations averaged 20 ng/g in leaves, and 5 in branches. The one data point for cores showed TCE at 7 ng/g. By contrast, mean TCE values in trees at the French drain ranged from non-detect to several hundreds ng/g in cores of trees growing in non-mixed soil. Similarly, CT was found at 22 ng/g mean value in background leaves, 11 in background branches, and at 5 ng/g in the one core data point. TCA was found rarely in background leaves, and never in background branches or cores. PCE showed low level but diffuse reportable concentrations in background leaves, but never in branches or cores.

One complication of having elevated TCE, PCE and CT backgrounds is that the discrimination between TCAA and true chloroform using the current method cannot be made. For this reason, results are reported as “mix” of TCAA and chloroform. The “TCAA and chloroform” mix was found in elevated levels in most background leaves and branches, consistently with the fact that whenever plants are exposed to TCE or PCE, their analytical content of chloroform can be elevated because of the formation and subsequent decarboxylation of TCAA.

In order to verify if this elevated background was an analytical artifact, samples from a spike experiment were collected in a split mode and forwarded to a different ANL lab for independent analysis. Although results (particularly chloroform mix) tended to be higher in the

ES lab (probably due to longer equilibration times and consequent more recovery and complete decarboxylation of TCAA), the data overall did not evidence any systematic variation of data that might point to a measurement or calibration error, or a lab cross-contamination. More work should be conducted next year to ascertain background conditions.

In the French Drain, this year samples included willows growing in the soil and several TreeWell® poplars growing in groundwater at the southernmost edge of the French Drain area. Samples were collected from willows growing in parts of the FD area that had been previously treated with the mixing/steam and iron filings process in 1997 ("mixed soil") and in areas that had not been previously treated ("non-mixed"). These two areas are expectedly different in contamination levels as the treatment had achieved more than 80% contaminant removal. As visible from Table 2 and Figure 2, mean values of most contaminants were found remarkably different between willows growing in mixed versus non-mixed soil. Non-mixed soil trees showed dramatically higher contaminant concentrations, probably reflecting the higher exposure levels of their root system. It is important to note that tree roots are effectively "averaging," or integrating exposure to different contaminant levels, as they extensively explore soil regions and pockets that would be very difficult and expensive to sample individually with conventional soil sampling methods. Based on the few collimating datapoints available at this time, a proof-of-concept correlation was attempted (reported in Figure 3) between soil concentration at depth (SAIC data were used) and tissue analysis. While results are encouraging and more datapoints should be collected to make it significant, soil sampling to deliver the desired level of statistical representativeness and meaningful, integrated mean concentrations is very expensive and complex.

Poplars growing in the French Drain groundwater (DD row) also showed elevated concentrations of contaminants, demonstrating that their roots are exposed to significant contamination from contact with the groundwater. Groundwater analysis (2002) from nearby well 317322 shows significant concentrations of chloroform, carbon tetrachloride, TCE, PCE but not 1,1,1 TCA.

Trunk core samples were initially collected from several heights from two willows (K100W and DD95W, both growing in non-mixed soil) to determine the effect of sampling height and core radial subsection on contaminant concentrations. Core samples are probably the best quantifiers of uptake rates (maximum concentrations found in aboveground tree tissue), as VOCs have been shown to diffuse through the bark as they move upwards and into the branches. Results are reported in Table 3. They show that concentrations tended to drop with height from ground surface, and that this drop tended to be more sensible in the outer section. This confirms what previously reported by others (Ma and Burken 2003). Core sampling, however, is an invasive procedure that can seriously damage small trees and represent a potential entry way for pests into older trees. It also cannot be replicated on the same tree to collect multiple samples. In order to minimize damage to the trees, subsequent core samples were only collected at the 60 cm height, and a number of plants were sampled so that a correlation between cores and branches could be established. Results are shown in Figure 4 for TCE. Analogous data were found for PCE. A strong and positive correlation ($R^2 = 0.97$) makes us believe that in the future the core sampling could be avoided and the branch data could be used to correctly estimate plant removal rates with no harm to the tree, and faster and easier sampling procedures.

When sampling a tree at all points (trunk core, branch, and leaf), data show a progressive decrease of concentration of VOCs from the core to the branch to the leaf (Figure 5). This pattern may be useful in discriminating airborne background levels from those resulting from root uptake.

Data collected from the Hydraulic Control area show a diffuse presence of TCE and CT, and a sporadic presence of PCE and 1,1,1 TCA in tissue from trees growing within the radiologically controlled HC area (rows M, N, O, P, and R). This area is where the groundwater is expectedly less deep and more contaminated, being closer to the source area. Downgradient trees outside the radiologically controlled area (rows S and beyond) sporadically reported measurable concentrations of VOCs in branches and cores, and diffuse presence of VOCs in leaves, often within the background range.

In order to determine which trees were within background levels and which had above-background concentrations (true positives), the following assumptions were made:

- Concentration higher than background mean (calculated including also campus trees).
- Presence of contaminant in branch and core (leaf concentration too variable).
- Presence of one or more contaminants.

Trees that matched the above conditions are highlighted in Table 3 and on the map in Figure 6. Plants that showed above-background levels are presumably in contact with the contaminated groundwater and sufficiently exposed to contaminants to reflect their exposure in their tissue. Because of the elevated potential for retardation of VOCs in the organic-rich backfill material in the root zone of the TreeWell® trees, however, non-detects do not necessarily imply that the roots have not reached the groundwater, as VOCs may be adsorbed and/or degraded in the rhizosphere before they actually reach the roots.

Tritium in Transpirate

Results from the tritium analyses are reported in Figure 7. The full set of data collected since the trees were planted is reported in Appendix 1. As reported in last year's summary, when comparing data from individual trees it is difficult to show a clear increase in tritium levels in each individual tree from previous years. However, trees vary widely in their concentration of tritium, and several of them growing immediately south of the 319 landfill have now shown to be well above our established background (approximately 14 TU, or 45 pCi/L). Concentrations in this area have been shown spanning from background to 136 TU (435 pCi/L) this summer. Trees with the highest levels of tritium in their transpirate were found in the first four rows south of the 319 landfill (P480, Q424, R384, R496, S392, S520, and T512, T528). The closest monitoring well (MW 319171) reported tritium concentrations around 2,500 pCi/L in 2002). Other data higher than background were found in the farthest southwest corner of the fenced area (rows R and T at 0).

Comparing data over time (temporal series) is another way to determine if the results from the treatment area are beginning to change. When examining the tritium data as cumulative

data from each sampling event, results begin to point to a more favorable trend. Figure 1 depicts the trends of tritium data per sampling event (mean, standard deviation, minimum and maximum values) over the years 2000-2003. Compared to the first years of growth, the summer 2002 and 2003 data show increased mean values, increased standard deviation (which implies larger data variability) and higher maximum values. Conversely, the background concentration has remained quite stable during the same time frame. This trend may be indicative of the fact that each sampled tree may be different from others in rooting depth and/or exposure to tritium in the subsurface. In other words, this data may indicate that some of the trees are indeed accessing, at least in part, the contaminated groundwater.

One important consideration for future monitoring plans regards the extent of mixing of tritiated with clean water at depth and their uptake by different plant roots. As tritium levels are still not quite at the concentrations found in nearby groundwater, some mixing is evident. Also, water taken up by the deepest tap root might be following a radially different route upwards than water taken up by lateral roots of the same tree. There are a number of factors that let us hypothesize that water taken up by the deeper tap root might feed the tallest branches and conversely lateral roots may feed radially pertinent branches. Segregated root "feeding" is well demonstrated in other disciplines, such as plant pathology, where bacterial or viral infections of the vascular system can be isolated on a specific side of the tree and relative branches. In order to determine within-tree differences in transpirate, different sampling approaches need to be organized. Attempts to organize a sample collection from the tallest branch or tree apex using a "cherry picker" (contacts made with PFS-Electrical group) failed this year and should be definitely planned for the 2004 summer.

Sap Flow Measurements

Data were automatically recorded by the datalogger system from mid June to the end of November; however, upon analysis of the output it was found that out of the 10 probes installed only three gave readable results. These results were, however, considered dubious and not fit for reporting. As the probes have gone beyond their expected life, cannot be recalibrated and are not "certified" by the manufacturer after their initial use, a decision needs to be made whether to purchase new probes for future monitoring. The data logging system itself is, however, in good working condition and is available with minor maintenance for future use.

Conclusions and Recommendations

As the trees complete their fourth growing season in the field, a significant amount of information has been collected to assess their performance at achieving the remedial objectives. From this data, the trees appear to have begun to influence the cleanup area significantly.

Based on this year's monitoring results, the following conclusions can be drawn:

- Background levels of VOCs were significantly more elevated this summer than in the past. We do not know the origin of this background. When so extensively reported, elevated background data need to be factored in when analyzing field data.

- Among background data, leaf data are significantly more variable than branch and core data, and this is explained with the large surface area of leaves compared to branches and trunk, which allows for higher deposition rates. In the presence of elevated background, leaf data are probably the least reliable of all tissue data and they should be considered only in conjunction with branch and core data, if at all.
- When determining background vs. real "hits," it is useful to take in consideration the presence of more than one contaminant, and especially the least common ones, and the pattern of concentration within tree tissues.
- Branch and core data show excellent correlation, therefore allowing us to estimate core concentration from branch data, with beneficial consequences to the tree's health and sampling times.
- Willows growing in soil with higher contamination showed much higher concentrations than willows in cleaner soil, thus suggesting a dose response.
- Concentrations in the order of hundreds and thousand ng/g in trunk core samples at the French Drain suggest a significant removal of VOCs by the plants in areas of higher contamination within the French Drain.
- Several poplars have shown to be in contact with groundwater both at French Drain and at the Hydraulic Control Area, based on higher than background levels of VOCs and of tritium in transpirate.
- Tritium levels in hydraulic control trees have been increasing over background over the last several years. Sampling should now include branches from the top (apical) part of the tree to determine if segregation of water by root type is occurring, as the apical leaves may be fed directly from the deepest roots in contact with tritium-rich groundwater.
- Adsorption/desorption studies should be conducted to determine retardation factors by backfill material.

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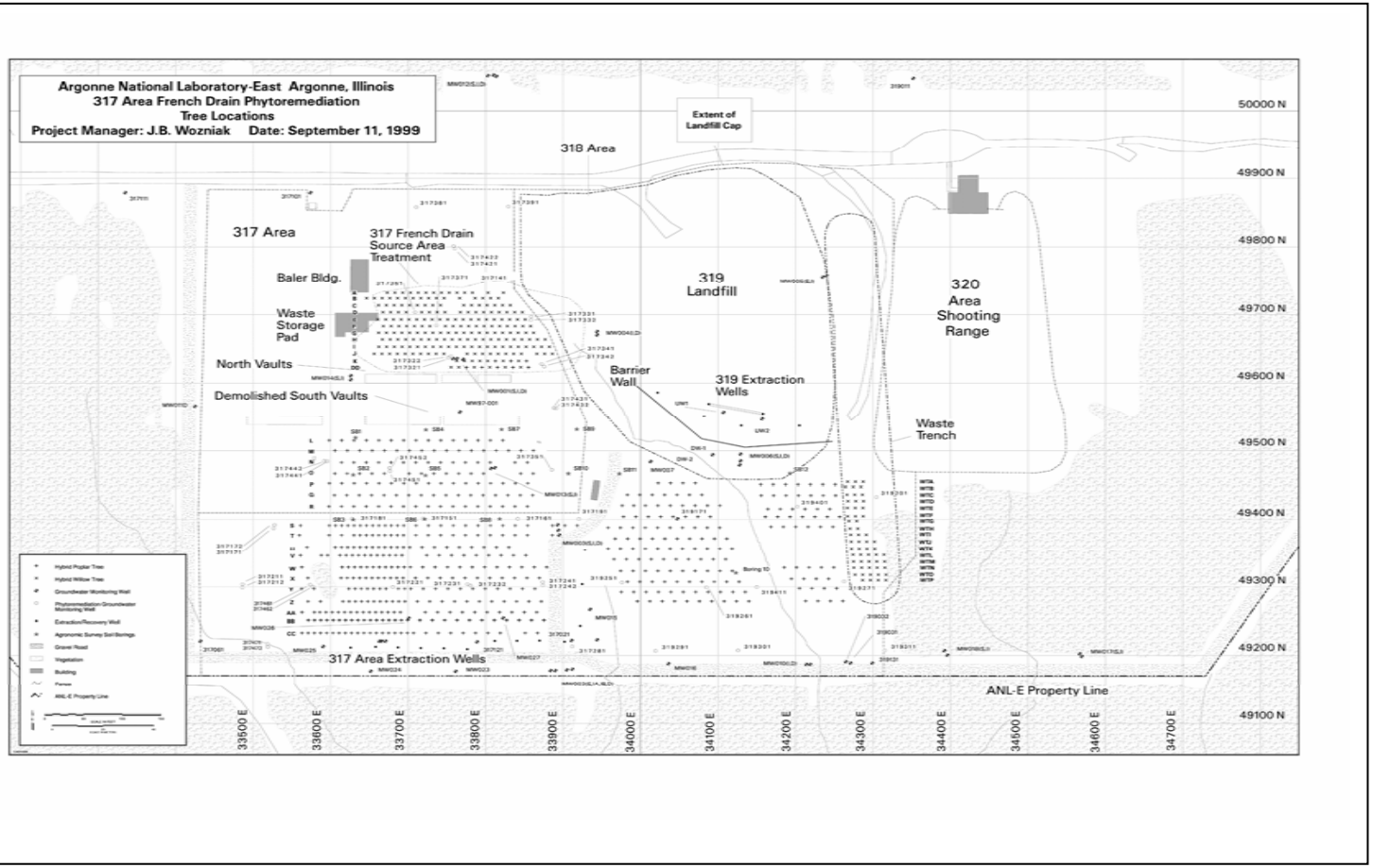

Figure 1. The 317/319 Phytoremediation Area.

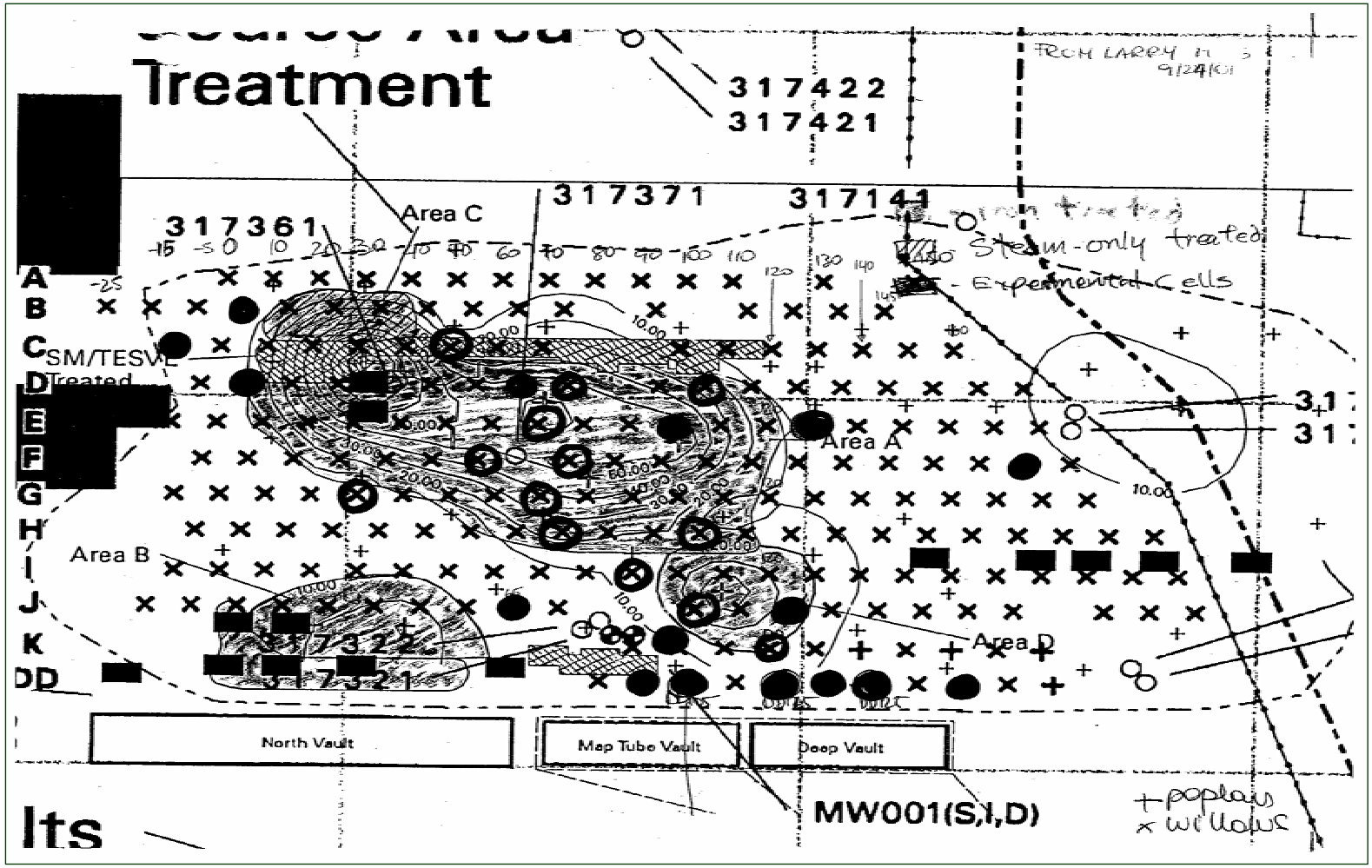

Figure 2. Results of French Drain sampling. (Filled circles = elevated concentrations. Outlined circles = lower concentrations.) (Grey area = "mixed" soil.)

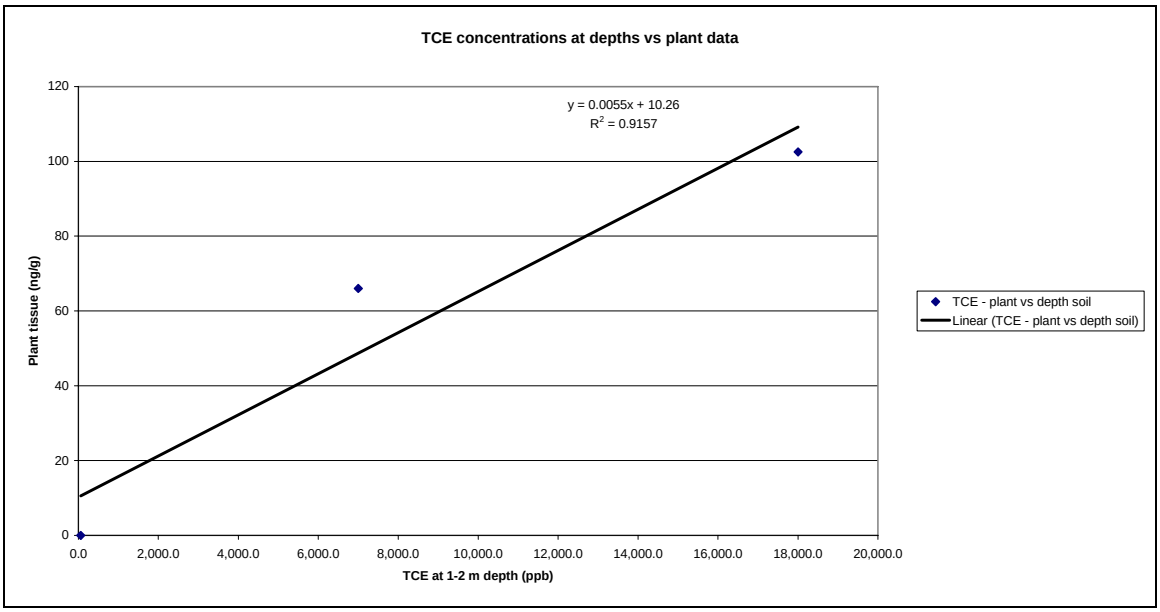

Figure 3. Proof-of concept correlation between soil TCE concentration at depth and tissue data (soil data from SAIC).

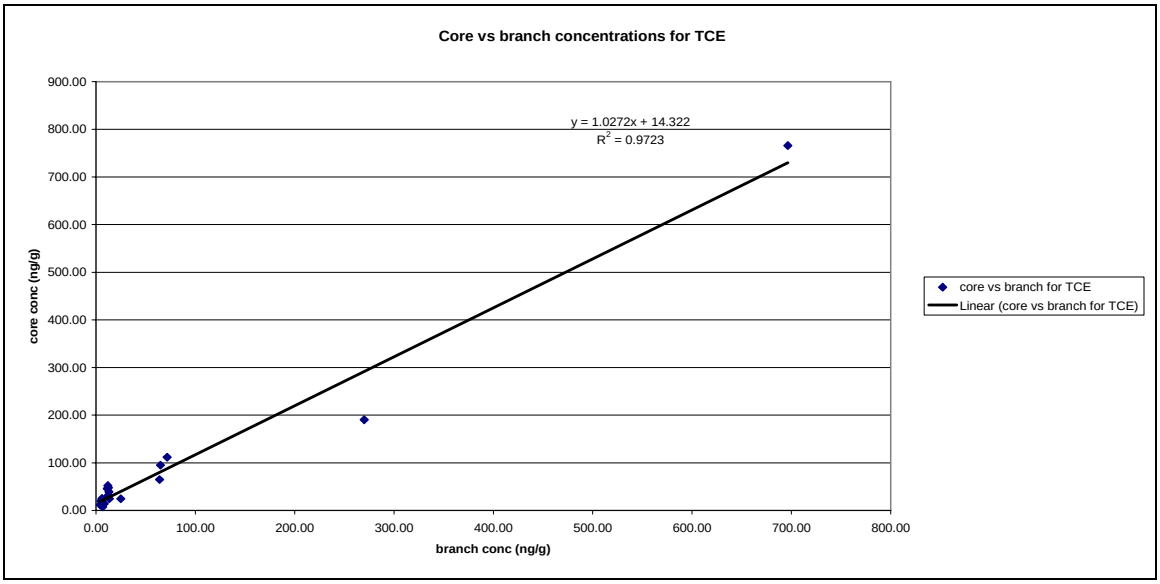

Figure 4. Correlation between branch and core concentrations of TCE, all samples (n=32).

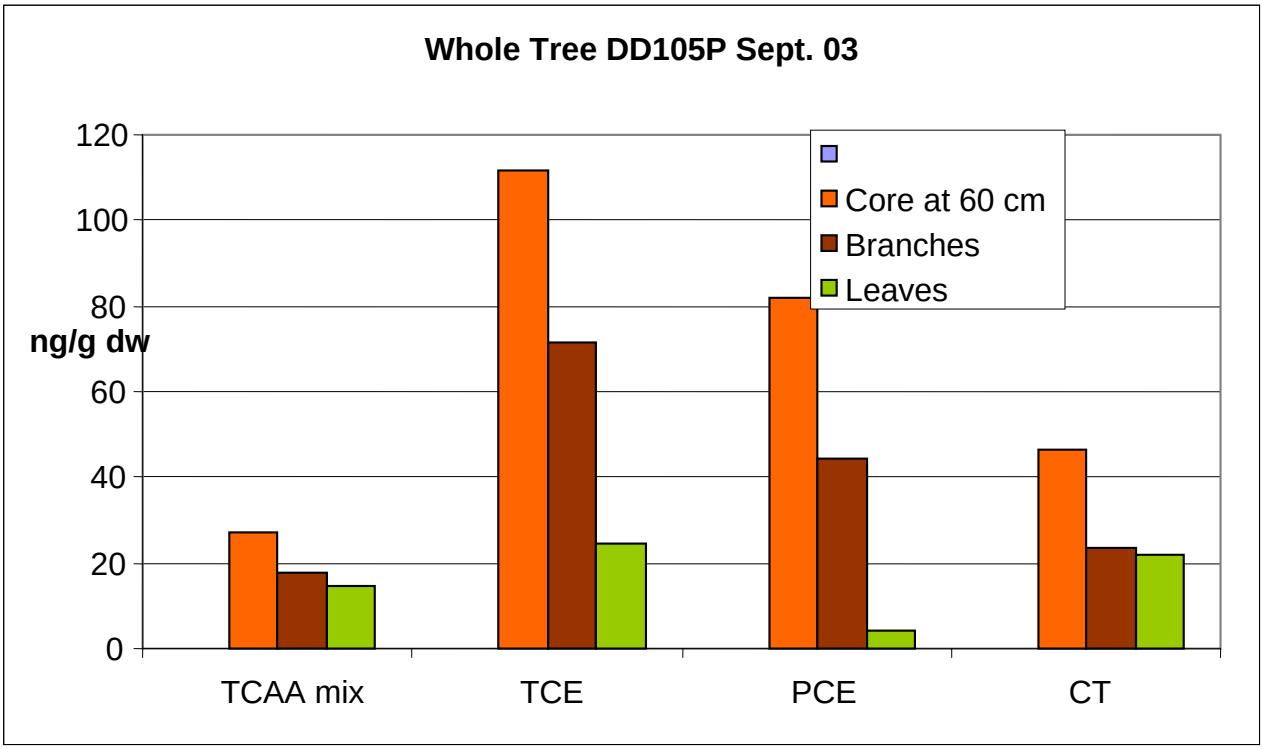

Figure 5. Loading losses in full tree sampling.

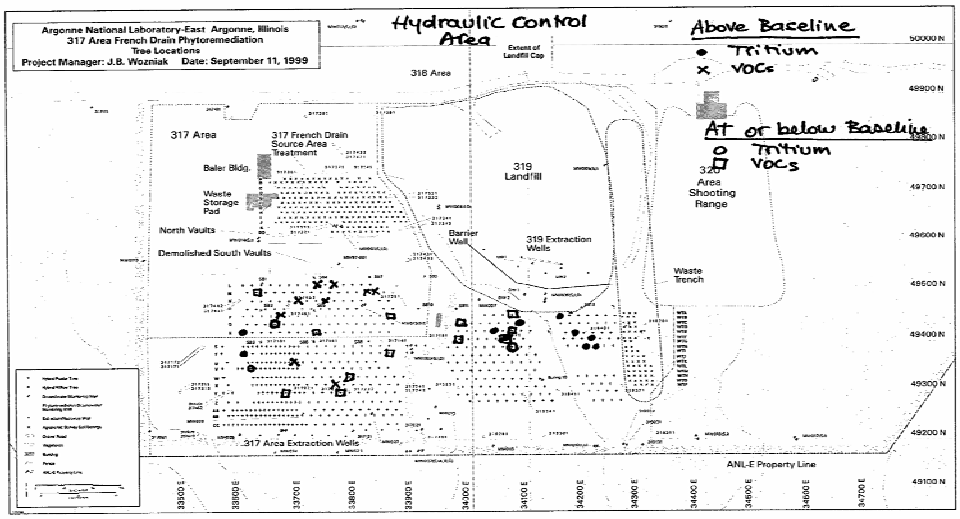

Figure 6. Sampling of Hydraulic Control areas – locations of samples above and below background levels.

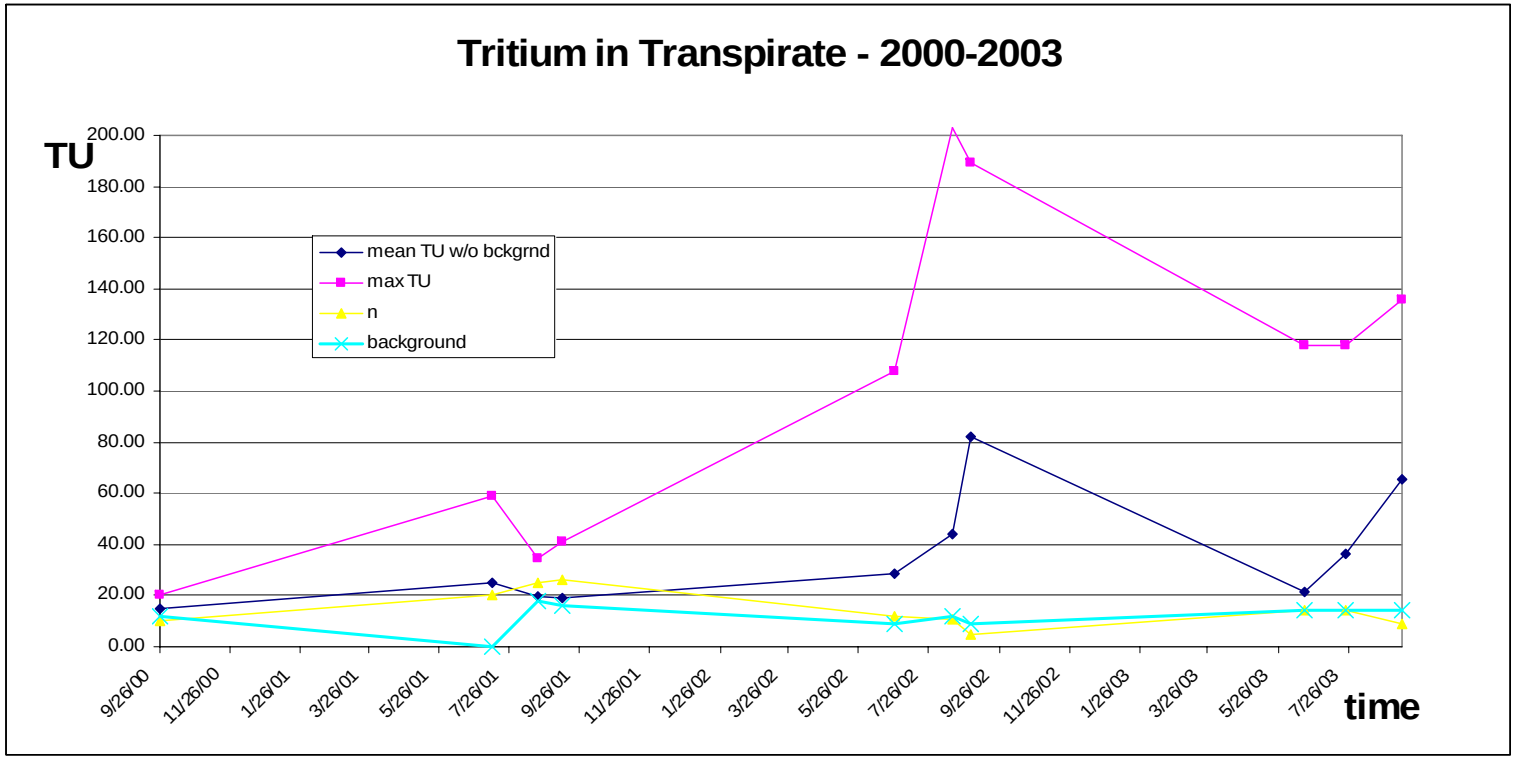

Figure 7. Tritium concentrations in transpirate (TU).

Table 1. Summary of Controls and background levels (MIX = unresolved mix of chloroform and TCAA), ng/g on dry weight.

Tree	TCE leaf	TCE branch	TCE core	PCE leaf	PCE Branch	PCE core	MIC leaf	MIX Branch	MIX core	TCA leaf	TCA Branch	TCA core	CT leaf	CT branch	CT core
Campus Background mean	36	5	NA	.8	<0.04	NA	221	114	<3		<2	NA	32	16	NA
Campus Background standard deviation	10.4	4.3	NA	0.24	NA	NA	25.3	29	NA	NA	NA	NA	14.4	9.7	NA
Greenhouse Poplars mean	16	7	7.3*	1	<0.04	<0.04	263	68	<3	<2	<2*	<2	11	5	5*
Greenhouse poplars standard deviation	5.7	1.9	NA	05	NA	NA	60	52	NA	4	NA	NA	6	2	NA
Control Willows‡	8	2	NA	0.1	<0.04	NA	2	2	NA	<2	<2	NA	16	12	NA
Control Willows standard deviation	11	3	NA	0.1	NA	NA	5	4	NA	NA	NA	NA	2	5	NA
Mean of all	20	5	7	0.8	<0.04	NA	174	55	NA	<2	<2	NA	22	11	5
Standard deviation of all	15	4	NA	0.6	NA	NA	120	52	NA	6	NA	NA	16	9	NA

*One data point only.
‡Includes willows at Greenhouse and at French Drain area.

Table 2. Summary of French Drain results (MIX = unresolved mix of chloroform and TCAA), ng/g on dry weight. Mixed refers to trees grown on mixed soil, non-mixed to those growing in non-mixed areas (higher soil contamination levels).

Tree	TCE leaf	TCE branch	TCE core	PCE leaf	PCE Branch	PCE core	MIX leaf	MIX branch	MIX core	TCA leaf	TCA branch	TCA core	CT leaf	CT branch	CT core
TreeWell Poplars mean	22	21	60	2.2	96	59	546	2,299	2,550	<2	11	6	22	164	298
Mean Mixed	15	7	33	.8	12	116	298	86	239	<2	<2	<2	22	9	14
Mean non-Mixed	13	114	130	.9	65	121	396	775	1,089	2	18	20	28	111	282

Table 3. Contaminant concentration in trunk cores at different heights above ground surface and different radial sections (ng/g on dry weight).

			TCE		PCE	
Date	Tree ID	cm Above ground	Outer section	Inner section	Outer section	Inner section
7/9/2003	K100W	30	56	41	59	27
	K100W	60	64	52	64	57
	K100W	90	45	46	46	55
	K100W	120	29	33	27	36
7/16/2003	DD95W	30	566	699	111	112
	DD95W	60	640	677	107	102
	DD95W	90	393	559	73	86
	DD95W	120	283	498	62	85

Table 4. Summary results of Hydraulic Control Area monitoring. Highlighted are datapoints above general background mean (ng/g on dry weight).

		TCE			PCE			TCAA+CHCl3			1,1,1-TCA			CCl4		
Tree ID	Date	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core
mean all back ground		20	5	7	0.8	0.04	0.04	174	55	3	<2	<2	<2	22	11	5.3
L128P	9/23/2003	< 4	64	8.33	14.33	< 0.04	< 0.04	< 3.00	< 3.00	52.33	< 2.15	< 2.15	< 2.15	14.33	6.00	8.00
L128P	10/23/2003	34	6.	19.00	< 0.04	< 0.04	2.00	249.00	64.00	*	< 2.15	3.00	< 2.15	19.50	4.00	11.00
L144P	10/23/2003	NA	12	30.50	NA	< 0.04	4.00	NA	162.50	163.00	NA	< 2.15	11.00	NA	< 2.67	< 2.67
L160P	9/23/2003	NA	4	12.00	NA	< 0.04	< 0.04	NA	5.20	< 3.00	NA	9.20	18.25	NA	< 2.67	< 2.67
M024P	10/10/2003	13	< 4.00	NA	1.00	< 0.04	NA	250.50	22.50	NA	< 2.15	< 2.15	NA	5.50	< 2.67	NA
M152P	10/23/2003	NA	6	25.00	NA	< 0.04	1.50	NA	68.50	*	NA	< 2.15	< 2.15	NA	3.50	17.00
M216P	10/7/2003	26	34	NA	1.50	< 0.04	NA	359.00	80.50	NA	< 2.15	< 2.15	NA	12.50	5.00	NA
M232P	10/23/2003	26	5	19.00	< 0.04	1.00	1.00	212.50	80.50	*	< 2.15	< 2.15	< 2.15	13.00	3.50	11.50
N096P	10/23/2003	18.00	5.00	20.00	< 0.04	< 0.04	0.00	183.00	24.50	< 3.00	< 2.15	< 2.15	< 2.15	9.50	3.50	12.50
N144P	10/23/2003	32.00	6.50	24.00	1.00	6.50	12.00	308.00	51.00	< 3.00	< 2.15	18.00	46.50	20.00	< 2.67	< 2.67
O264P	10/6/2003	24.50	< 4.00	NA	0.50	1.00	NA	433.00	65.00	NA	< 2.15	< 2.15	NA	8.00	< 2.67	NA
P064P	10/10/2003	18.50	< 4.00	NA	2.00	1.00	NA	244.50	6.00	NA	< 2.15	4.00	NA	15.00	< 2.67	NA
P240P	10/10/2003	18.00	< 4.00	NA	1.00	< 0.04	NA	211.00	31.00	NA	< 2.15	< 2.15	NA	14.00	3.00	NA
Q328P	10/10/2003	21.50	< 4.00	NA	1.50	< 0.04	NA	200.00	45.50	NA	< 2.15	< 2.15	NA	16.00	3.00	NA
R000P	10/10/2003	24.50	< 4.00	NA	2.00	< 0.04	NA	253.50	36.50	NA	< 2.15	< 2.15	NA	20.00	4.50	NA
R032P	10/7/2003	19.50	< 4.00	NA	1.50	< 0.04	NA	144.50	79.50	NA	< 2.15	2.50	NA	24.50	8.00	NA
R128P	10/7/2003	21.00	< 4.00	NA	1.50	< 0.04	NA	181.00	69.50	NA	< 2.15	3.00	NA	< 2.67	5.50	NA
R128P	10/10/2003	23.50	< 4.00	NA	1.50	< 0.04	NA	298.50	45.00	NA	< 2.15	7.50	NA	15.50	< 2.67	NA
R416P	10/10/2003	8.50	< 4.00	NA	1.00	< 0.04	NA	82.50	12.50	NA	< 2.15	6.50	NA	14.00	< 2.67	NA
S128P	10/8/2003	20.50	< 4.00	NA	4.50	< 0.04	NA	217.00	40.00	NA	< 2.15	< 2.15	NA	19.50	4.50	NA
S128P	10/9/2003	36.50	< 4.00	NA	2.50	< 0.04	NA	352.50	44.00	NA	< 2.15	< 2.15	NA	17.00	5.00	NA
S144P	10/8/2003	19.00	< 4.00	NA	0.50	< 0.04	NA	92.50	35.50	NA	< 2.15	3.00	NA	23.50	4.50	NA
S328P	10/9/2003	21.50	< 4.00	NA	1.50	< 0.04	NA	238.50	20.00	NA	< 2.15	< 2.15	NA	20.00	4.00	NA
S392P	10/8/2003	23.50	< 4.00	NA	2.00	< 0.04	NA	293.50	23.50	NA	< 2.15	< 2.15	NA	< 2.67	< 2.67	NA
T000P	10/9/2003	27.50	< 4.00	NA	1.50	< 0.04	NA	193.50	132.00	NA	< 2.15	< 2.15	NA	11.00	9.00	NA

Table 4. Summary results of Hydraulic Control Area monitoring. Highlighted are datapoints above general background mean (ng/g on dry weight).

		TCE			PCE			TCAA+CHCl3			1,1,1-TCA			CCl4		
Tree ID	Date	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core
T072P	10/8/2003	47.50	< 4.00	NA	2.50	< 0.04	NA	293.50	54.00	NA	< 2.15	< 2.15	NA	14.50	4.00	NA
T256P	10/8/2003	13.00	< 4.00	NA	< 0.04	< 0.04	NA	220.50	49.00	NA	< 2.15	< 2.15	NA	5.50	< 2.67	NA
T400P	10/9/2003	25.00	< 4.00	NA	1.50	< 0.04	NA	234.50	41.00	NA	< 2.15	< 2.15	NA	16.00	5.00	NA
V080P	10/8/2003	20.50	< 4.00	NA	1.50	< 0.04	NA	350.00	42.50	NA	< 2.15	2.50	NA	17.50	4.00	NA
W184P	10/9/2003	40.00	< 4.00	NA	2.00	< 0.04	NA	313.50	42.50	NA	< 2.15	< 2.15	NA	10.00	6.00	NA
X160P	10/8/2003	17.50	< 4.00	NA	1.50	< 0.04	NA	239.50	70.50	NA	< 2.15	3.00	NA	26.00	< 2.67	NA
Y084P	10/9/2003	31.00	< 4.00	NA	1.50	< 0.04	NA	367.50	41.50	NA	< 2.15	< 2.15	NA	12.50	5.50	NA
Y168P	10/9/2003	31.50	< 4.00	NA	1.50	< 0.04	NA	270.50	245.00	NA	< 2.15	< 2.15	NA	5.00	5.00	NA

APPENDIX 1

Summary of Controls and Background - Summer 2003

		TCE			PCE			TCAA+CHCl3			1,1,1-TCA			CCl4		
Tree ID	Date	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core
FD ctrl W	7/9/2003	0.00	na		<0.04	na		0.00	na							
FD ctrl W	9/19/2003	20.67	7.00	NA	< 0.04	< 0.04	NA	11.33	8.00	NA	< 2.15	< 2.15	NA	17.67	15.67	NA
FD ctrl W	9/25/2003	19.3	0	na	0.3	0	na	0	0	na	0	0	na	15	8	na
GH ctrl W	6/30/2003	0	0		,0.04	0		0	0							
GH ctrl W	7/16/2003	0.00	0.00		<0.04	0.00		0.00	0.00							
GHCPA	9/23/2003	7.33	6.67	7.33	0.67	< 0.04	< 0.04	< 3.00	9.33	< 3.00	< 2.15	< 2.15	< 2.15	9.67	2.67	5.33
GHCPA	10/2/2003	19.50	6.00	NA	1.00	< 0.04	NA	228.50	134.50	NA	16.50	< 2.15	NA	< 2.67	< 2.67	NA
GHCPA	10/7/2003	16.50	< 4.00	NA	1.50	< 0.04	NA	319.50	46.50	NA	< 2.15	< 2.15	NA	6.00	6.00	NA
GHCPA	10/8/2003	15.00	< 4.00	NA	2.00	< 0.04	NA	260.00	30.50	NA	< 2.15	< 2.15	NA	< 2.67	< 2.67	NA
GHCPA	10/9/2003	13.50	4.00	NA	1.00	< 0.04	NA	278.50	50.00	NA	< 2.15	< 2.15	NA	20.00	8.00	NA
GHCPA	10/10/2003	13.00	< 4.00	NA	1.00	< 0.04	NA	216.50	31.50	NA	< 2.15	< 2.15	NA	13.50	3.50	NA
GHCPC	10/2/2003	18.00	8.00	NA	1.50	< 0.04	NA	356.50	153.50	NA	11.00	< 2.15	NA	4.50	3.00	NA
GHP0C	10/23/2003	27.00	9.00	NA	0.50	< 0.04	NA	183.50	85.00	NA	< 2.15	< 2.15	NA	< 2.67	< 2.67	NA
Campus trees																
woods-tree	11/5/2003	41.00	2.67	NA	< 0.04	< 0.04	NA	< 3.00	< 3.00	NA	< 2.15	< 2.15	NA	22.00	6.00	NA
#212-tree	11/5/2003	52.00	2.33	NA	< 0.04	< 0.04	NA	267.00	< 3.00	NA	< 2.15	< 2.15	NA	22.33	16.67	NA
#213-tree	11/5/2003	22.67	1.00	NA	0.67	< 0.04	NA	199.67	134.00	NA	< 2.15	< 2.15	NA	19.33	8.67	NA
#335-tree	11/5/2003	24.67	< 4.0	NA	< 0.04	< 0.04	NA	216.00	93.00	NA	< 2.15	< 2.15	NA	28.67	8.33	NA
#362-tree	11/5/2003	43.00	13.00	NA	1.00	< 0.04	NA	226.00	< 3.00	NA	< 2.15	< 2.15	NA	41.67	22.00	NA
#438-tree	11/5/2003	32.33	4.67	NA	< 0.04	< 0.04	NA	197.00	< 3.00	NA	< 2.15	< 2.15	NA	60.00	33.67	NA
	mean campus trees	35.94	4.73	na	0.83	<0.04	na	221.13	113.50	<3	<2.15	<2.15	<2.15	32.33	15.89	na
	stdev	10.41	4.30	NA	0.24	na	NA	25.29	28.99	NA	na	na	NA	14.39	9.67	NA
	Maximum	52.00	13.00	7.33	0.67	<0.04	<0.04	267.00	153.00	<3	<2.15	<2.15	<2.15	60.00	33.67	5.33
	Minimum	22.67	<4	na	<0.04	<0.04	na	<3	<3	na	<2.15	<2.15	na	19.33	6.00	na
	GH ctrl P															
	means	16.23	6.73	7.33	1.15	<0.04	<0.04	263.29	67.60	<3	13.75	<2.15	<2.15	10.73	4.63	5.33
	stdev	5.712655	1.920648	na	0.491495	na	na	60.35441	52.080671	na	3.889087	na	na	6.243441	2.2925	na
	mean +stdev	21.94	7.63	7.33	1.64	<0.04	<0.04	323.64	119.68	<3	4.93	<2.15	<2.15	13.69	6.93	5.33
	Ctrl Willows															
	mean	7.99	1.75	na	0.30	0.00	na	2.27	2.00	na	0.00	0.00	na	16.33	11.83	na
	Stdev	10.95598	na	na	#DIV/0!	0	na	5.068421	4	na	#DIV/0!	#DIV/0!	na	1.885618	5.421152	na
Mean of all Background		20.29	4.60	7.33	1.01	0.00	na	174.12	55.42	#DIV/0!	9.17	0.00	#DIV/0!	21.56	10.94	5.33
	stdev	14.54	3.87	0.00	0.49	0.00	na	119.69	53.83	na	6.39	na	na	15.90	9.34	0.00

Note: some concentrations reported below detection limits reported as 0 to allow spreadsheet calculations

French Drain - Summer 2003 Summary Table

Average of 2 or 3 determinations

			TCE			PCE			TCAA+CHCl3			1,1,1-TCA			CCl4		
Tree ID	**Soil Type**	**Date**	**Leaf**	**Branch**	**Core**	**Leaf**	**Branch**	**Core**	**Leaf**	**Branch**	**Core**	**Leaf**	**Branch**	**Core**	**Leaf**	**Branch**	**Core**
FD ctrl W	c	7/9/2003	0.00	na		0.00	na		0.00	na							
FD ctrl W	c	9/19/2003	20.67	7.00	NA	< 0.04	< 0.04	NA	11.33	8.00	NA	< 2.15	< 2.15	NA	17.67	15.67	NA
FD ctrl W	c	9/25/2003	19.30	0.00	na	0.30	0.00	na	0.00	0.00	na	0.00	0.00	na	15.00	8.00	na
GH ctrl W	c	6/30/2003	0	0		0	0		0	0							
GH ctrl W	c	7/16/2003	0.00	0.00		0.00	0.00		0.00	0.00							
DD105P	g	9/19/2003	24.67	7.00	111.67	4.00	44.33	59.33	14.67	18.00	27.00	< 2.15	< 2.15	< 2.15	21.67	23.33	46.33
DD105P	g	10/23/2003	15.00	12.00	52.00	1.00	6.50	36.00	1339.00	236.50	511.00	< 2.15	< 2.15	6.00	29.00	11.00	24.50
DD125P	g	10/6/2003	38.50	31.50	NA	2.00	95.00	NA	567.00	4521.50	NA	< 2.15	16.00	NA	16.00	36.50	NA
DD125P	g	10/23/2003	12.00	13.00	39.00	1.00	22.50	47.50	800.50	1158.00	1927.00	< 2.15	< 2.15	< 2.15	18.50	62.50	153.00
DD145P	g	10/6/2003	34.50	25.50	NA	5.50	250.00	NA	551.50	5241.50	NA	< 2.15	13.50	NA	30.00	44.50	NA
DD145P	g	10/23/2003	8.50	64.00	65.50	2.00	328.00	147.00	454.50	6684.00	9904.50	< 2.15	< 2.15	< 2.15	15.00	1103.00	1229.00
DD165P	g	10/6/2003	19.00	4.00	NA	2.00	15.50	NA	347.00	287.00	NA	< 2.15	4.00	NA	17.00	11.00	NA
DD165P	g	10/23/2003	24.00	12.50	32.00	0.50	3.00	4.50	297.00	242.50	383.50	< 2.15	< 2.15	< 2.15	27.50	23.50	38.50
C050W	m	10/23/2003	19.50	11.50	60.00	1.50	100.50	475.00	1661.50	105.50	258.00	< 2.15	< 2.15	< 2.15	< 2.67	< 2.67	< 2.67
D065W	m	6/30/2003	9.00	7.00		1.00	10.00		161.00	0.00							
D075W	m	10/23/2003	30.00	15.00	24.00	1.00	3.50	54.50	373.00	118.50	250.00	< 2.15	< 2.15	< 2.15	< 2.67	< 2.67	< 2.67
D105W	m	10/23/2003	16.00	8.50	19.00	1.00	15.00	30.50	595.00	97.50	138.50	< 2.15	< 2.15	< 2.15	24.00	4.50	12.50
E070W	m	6/30/2003	tr	0.00		tr	1.00		0.00	0.00							
E100W	m	7/8/2003	tr	0.00		tr	5.00		115.00	0.00							
F055W	m	6/30/2003	0.00	0.00		0.00	1.00		143.00	0.00							
F075W	m	6/25/2003	tr	0.00		tr	1.00		60.00	0.00							
G070W	m	6/30/2003	tr	5.00		tr	2.00		109.00	0.00							
H075W	m	10/23/2003	12.50	14.50	36.00	1.00	2.00	6.00	330.50	195.50	< 3.00	< 2.15	< 2.15	< 2.15	18.50	5.50	16.00
H105W	m	7/8/2003	tr	0.00		tr	1.00		0.00	0.00							
J105W	m	10/23/2003	18.50	25.00	24.50	0.50	6.00	13.00	326.00	363.50	311.00	< 2.15	< 2.15	< 2.15	24.50	16.00	14.50
J125W	m	7/8/2003	tr	0.00		tr	11.00		0.00	243.00							
B005W	n	8/11/2003	0.00	249.00		0.00	13.00		99.00	609.00							
B005W	n	10/10/2003	13.50	62.00	NA	2.00	195.50	NA	1115.00	84.50	NA	< 2.15	3.00	NA	< 2.67	6.00	NA
B005W	n	10/23/2003	25.00	36.00	45.00	2.00	167.50	176.50	2850.00	88.00	< 3.00	< 2.15	< 2.15	< 2.15	< 2.67	< 2.67	< 2.67
B005W	n	6/16/2003	0.00	46.00		0.00	80.00		0.00	0.00							
C(-10)W	n	6/25/2003	tr	53.00		tr	48.00		193.00	49.00							
C(-10)W	n	8/11/2003	0.00	0.00		0.00	11.00		0.00	241.00							
C0W	n	6/25/2003	tr	12.00		tr	8.00		98.00	0.00							
C0W	n	8/11/2003	0.00	0.00		0.00	0.00		0.00	0.00							
D005W	n	6/25/2003	tr	21.00		tr	32.00		128.00	0.00							
D005W	n	8/11/2003	0	0.00		0	3.00		106.00	0.00							
DD095W	n	7/8/2003	tr	173.00		tr	9.00		108.00	420.00							
DD095W	n	10/7/2003	26.50	1262.50	NA	3.00	416.00	NA	882.50	6272.00	NA	5.50	47.50	NA	54.00	163.50	NA
DD095W	n	10/23/2003	33.00	696.50	766.00	1.00	131.00	251.00	1041.00	5527.00	3145.50	< 2.15	14.50	16.50	78.50	671.50	1526.00
DD135W	n	10/23/2003	9.50	12.50	47.50	1.00	22.50	52.50	301.50	1183.00	1886.50	< 2.15	< 2.15	< 2.15	18.50	50.50	223.00
E130W	n	10/23/2003	21.50	9.00	21.50	1.00	16.00	27.00	292.50	52.50	< 3.00	< 2.15	5.00	< 2.15	25.00	< 2.67	10.50
F185W	n	8/8/2003	tr	11.00		tr	2.00		31.00	7.00							
F185W	n	10/23/2003	19.50	8.00	25.00	1.00	5.50	20.00	348.00	59.50	142.50	< 2.15	3.50	23.00	26.00	< 2.67	< 2.67
G030W	n	10/23/2003	23.00	14.00	28.50	1.50	68.50	73.00	345.50	90.00	305.00	< 2.15	< 2.15	< 2.15	< 2.67	< 2.67	< 2.67

I090W	n	10/23/2003	20.50	20.00	52.50	1.00	4.00	9.50	492.00	229.00	563.00	< 2.15	< 2.15	< 2.15	38.50	10.50	17.50
J065W	n	6/25/2003	tr	19		tr	2		166	177							
J065W	n	8/11/2003	0	9		0	2		20	6							
K100W	n	6/16/2003	0.00	34.00		0.00	19.00		0.00	61.00							
K100W	n	6/20/2003	na	21.00		na	15.00		na	411.00							
K100W	n	7/9/2003	0.00	11.00		tr	2.00		129.00	249.00							
K100W	n	9/19/2003	21.00	266.67	190.50	2.00	372.00	398.00	10.00	169.00	114.00	< 2.15	< 2.15	< 2.15	7.67	38.00	77.00
K100W	n	10/2/2003	16.50	71.50	NA	1.00	80.00	NA	730.50	2474.50	NA	22.00	35.00	NA	3.00	3.00	NA
K100W	n	10/23/2003	29.00	65.50	95.00	0.50	68.00	183.50	767.00	2922.50	2047.00	< 2.15	< 2.15	< 2.15	16.50	45.00	102.50
K120W	n	10/23/2003	15.00	13.50	24.50	1.00	16.50	20.00	442.50	321.50	508.00	< 2.15	< 2.15	< 2.15	11.00	14.00	17.50
			TCE			PCE			TCAA + Chloroform			1,1,1,TCA			CCl4		
			Leaf	Branch	core	Leaf	branch	core	leaf	branch	core	leaf	branch	core	leaf	Branch	Core
mean control		(willows)	7.99	1.75	na	0.08	0.00	na	2.27	2.00	na	<2.15	<2.15	na	16.33	11.83	na
mean groundwater		(poplars)	22.02	21.19	60.03	2.25	95.60	58.87	546.40	2298.63	2550.60	<2.15	11.17	6.00	21.83	164.42	298.27
mean mixed		(willows)	15.07	6.65	32.70	0.86	12.23	115.80	298.00	86.42	239.38	<2.15	<2.15	<2.15	22.33	8.67	14.33
mean non mixed		(willows)	13.02	114.17	129.60	0.90	64.61	121.10	396.15	775.11	1088.94	na*	na*	na*	27.87	111.33	282.00
m= mixed soil								*means contain many det limits									
n= non mixed																	
g= groundwater (treeWell)																	
c= control willows																	
controp poplars reported in HC table																	

Hydraulic Control – Summer 2003 Summary Table

Average of 2 or 3 determinations

		TCE			PCE			TCAA+CHCl3			1,1,1-TCA			CCl4		
Tree ID	Date	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core	Leaf	Branch	Core
mean all background		20	5	7	0.8	0.04	0.04	174	55	3	<2	<2	<2	22	11	5.3
L128P	9/23/2003	< 4.00	64.00	8.33	14.33	< 0.04	< 0.04	< 3.00	< 3.00	52.33	< 2.15	< 2.15	< 2.15	14.33	6.00	8.00
L128P	10/23/2003	34.00	6.00	19.00	< 0.04	< 0.04	2.00	249.00	64.00	*	< 2.15	3.00	< 2.15	19.50	4.00	11.00
L144P	10/23/2003	NA	12.50	30.50	NA	< 0.04	4.00	NA	162.50	163.00	NA	< 2.15	11.00	NA	< 2.67	< 2.67
L160P	9/23/2003	NA	4.20	12.00	NA	< 0.04	< 0.04	NA	5.20	< 3.00	NA	9.20	18.25	NA	< 2.67	< 2.67
M024P	10/10/2003	13.00	< 4.00	NA	1.00	< 0.04	NA	250.50	22.50	NA	< 2.15	< 2.15	NA	5.50	< 2.67	NA
M152P	10/23/2003	NA	6.50	25.00	NA	< 0.04	1.50	NA	68.50	*	NA	< 2.15	< 2.15	NA	3.50	17.00
M216P	10/7/2003	26.50	34.50	NA	1.50	< 0.04	NA	359.00	80.50	NA	< 2.15	< 2.15	NA	12.50	5.00	NA
M232P	10/23/2003	26.00	5.50	19.00	< 0.04	1.00	1.00	212.50	80.50	*	< 2.15	< 2.15	< 2.15	13.00	3.50	11.50
N096P	10/23/2003	18.00	5.00	20.00	< 0.04	< 0.04	0.00	183.00	24.50	< 3.00	< 2.15	< 2.15	< 2.15	9.50	3.50	12.50
N144P	10/23/2003	32.00	6.50	24.00	1.00	6.50	12.00	308.00	51.00	< 3.00	< 2.15	18.00	46.50	20.00	< 2.67	< 2.67
O264P	10/6/2003	24.50	< 4.00	NA	0.50	1.00	NA	433.00	65.00	NA	< 2.15	< 2.15	NA	8.00	< 2.67	NA
P064P	10/10/2003	18.50	< 4.00	NA	2.00	1.00	NA	244.50	6.00	NA	< 2.15	4.00	NA	15.00	< 2.67	NA
P240P	10/10/2003	18.00	< 4.00	NA	1.00	< 0.04	NA	211.00	31.00	NA	< 2.15	< 2.15	NA	14.00	3.00	NA
Q328P	10/10/2003	21.50	< 4.00	NA	1.50	< 0.04	NA	200.00	45.50	NA	< 2.15	< 2.15	NA	16.00	3.00	NA
R000P	10/10/2003	24.50	< 4.00	NA	2.00	< 0.04	NA	253.50	36.50	NA	< 2.15	< 2.15	NA	20.00	4.50	NA
R032P	10/7/2003	19.50	< 4.00	NA	1.50	< 0.04	NA	144.50	79.50	NA	< 2.15	2.50	NA	24.50	8.00	NA
R128P	10/7/2003	21.00	< 4.00	NA	1.50	< 0.04	NA	181.00	69.50	NA	< 2.15	3.00	NA	< 2.67	5.50	NA
R128P	10/10/2003	23.50	< 4.00	NA	1.50	< 0.04	NA	298.50	45.00	NA	< 2.15	7.50	NA	15.50	< 2.67	NA
R416P	10/10/2003	8.50	< 4.00	NA	1.00	< 0.04	NA	82.50	12.50	NA	< 2.15	6.50	NA	14.00	< 2.67	NA
S128P	10/8/2003	20.50	< 4.00	NA	4.50	< 0.04	NA	217.00	40.00	NA	< 2.15	< 2.15	NA	19.50	4.50	NA
S128P	10/9/2003	36.50	< 4.00	NA	2.50	< 0.04	NA	352.50	44.00	NA	< 2.15	< 2.15	NA	17.00	5.00	NA
S144P	10/8/2003	19.00	< 4.00	NA	0.50	< 0.04	NA	92.50	35.50	NA	< 2.15	3.00	NA	23.50	4.50	NA
S328P	10/9/2003	21.50	< 4.00	NA	1.50	< 0.04	NA	238.50	20.00	NA	< 2.15	< 2.15	NA	20.00	4.00	NA
S392P	10/8/2003	23.50	< 4.00	NA	2.00	< 0.04	NA	293.50	23.50	NA	< 2.15	< 2.15	NA	< 2.67	< 2.67	NA
T000P	10/9/2003	27.50	< 4.00	NA	1.50	< 0.04	NA	193.50	132.00	NA	< 2.15	< 2.15	NA	11.00	9.00	NA
T072P	10/8/2003	47.50	< 4.00	NA	2.50	< 0.04	NA	293.50	54.00	NA	< 2.15	< 2.15	NA	14.50	4.00	NA
T256P	10/8/2003	13.00	< 4.00	NA	< 0.04	< 0.04	NA	220.50	49.00	NA	< 2.15	< 2.15	NA	5.50	< 2.67	NA
T400P	10/9/2003	25.00	< 4.00	NA	1.50	< 0.04	NA	234.50	41.00	NA	< 2.15	< 2.15	NA	16.00	5.00	NA
V080P	10/8/2003	20.50	< 4.00	NA	1.50	< 0.04	NA	350.00	42.50	NA	< 2.15	2.50	NA	17.50	4.00	NA
W184P	10/9/2003	40.00	< 4.00	NA	2.00	< 0.04	NA	313.50	42.50	NA	< 2.15	< 2.15	NA	10.00	6.00	NA
X160P	10/8/2003	17.50	< 4.00	NA	1.50	< 0.04	NA	239.50	70.50	NA	< 2.15	3.00	NA	26.00	< 2.67	NA
Y084P	10/9/2003	31.00	< 4.00	NA	1.50	< 0.04	NA	367.50	41.50	NA	< 2.15	< 2.15	NA	12.50	5.50	NA
Y168P	10/9/2003	31.50	< 4.00	NA	1.50	< 0.04	NA	270.50	245.00	NA	< 2.15	< 2.15	NA	5.00	5.00	NA

higher than all background mean

Tritium in Leaf Transpirate - 2000-2003 Data

	9/26/2000		07/11/01		08/20/01		09/10/01		6/26/2002		8/15/2002		9/1/2002		6/18/2003		7/24/2003		9/10/2003	
Tree ID	TU	Std. Dev.	TU	Std. Dev.	TU	Std.Dev.	TU	Std. Dev	TU	Std. Dev.	TU	Std.Dev.	TU	Std. Dev.	TU	Std dev	TU	Std. Dev	TU	Std. Dev
AA563P			22	3.7	24.9	2.7	12.4	2.9												
M216P					11.8	2.9	11	3.3												
P000P					22	3.6	16.6	3.7												
P064P			23.7	3.8	26.9	3.4	15.1	3.9												
P256P					21.4	3.7	17.4	4.5												
P480P																			82.7	4.4
Q056P			28.4	2.5	25.8	3.3	21.7	3.7	14.1	3	<22						11.6	3.8		
Q344P					23.3	4.8	20.4	4.6												
Q392P															21.8	3.7				
Q424P															29	3.8			48	3.9
R000P			58.9	3.7					52.8	2.9	40.2	3	56.4	3.1			37.2	3.9		
R384															79.9	3.8			84.2	4.1
R416P					22.6	4.5	24.4	2.3												
R496P									20.3	2.5	16.2	2.3					118	4	38.5	3.9
R512P	11.5	3.8																		
R512P															9.9	3.17				
R528P															11.6	3.2				
R544P															12.8	3.2				
S016P	15.1	3.9	14.7	3	14.3	3.1	16.4	3.8												
S032P			18.7	2.9	15.4	3.5	11.6	3.4												
S048P	13.3	3.6																		
S112P	12	3.7																		
S128P	19.1	4.6																		
S144P			<13		14.6	3.5	12.8	3.2												
S176P			17.5	2.5	12	2.5	15.2	3.7												
S328P					14.6	4	9.4	3	13.3	2.8	<25						10.2	3.3		
S344P															9.9	3.2				
S392P	20.1	4.2	22.3	2.6	29.3	4.2	31.3	2.6	26	3.3	40.3	3.2	36	2.6			67.8	3.7	48	3.9
S408P	12.2	4																		
S520P									108	4	203	4	189	4			46.7	3.6	136	5
T000P			19.7	3.7	18	3.5	26	4.3	16.7	2.8	12.6	2.2					31.2	3.4		
T016P			13.9	3.3	20.1	3.8	15.7	3.2												
T096P			18.1	3.3	16.5	3.4	21.8	4												
T160P			23.9	3.7	15	3.3	16.8	3.1												
T256P			20.3	2.4	17.6	4	21.7	2.9												
T400P			27.1	3.4	17.5	4	23.7	2.6	17.3	2.4	27.7	3.2					25.5	3.4		
T512P															25.1	3.8			54.1	3.9
T528P			51.7	3.6	34.8	3.6	41.3	2.8	20.6	3.9	38.3	2.7	48	3.7			16.5	3.7	31.8	3.7
T544P															12.1	3.7				
T560P															14.2	3.2				
U424P															11.6	3.8				
V016P									12.9	2.4	6.4	1.85					13.6	3.3		
W424P			20.6	3.5	16.9	3.2	21.8	4.4												
WT Poplar §			36.6	2.7			14.4	2.6												
X194P			11.7	2.9	<60		11.7	3.5												
X416P			27.6	3.4	19.8	2.8	24	4.1	9.82	2.67	12.3	3					18	3.3		
Z448P	14.3	3.5																		
GHCtrl	11.4	3.6																		
Greenhouse ctrl	12.4	4.1	N/a		18	3.3	16	2.7	<8.6				<9.05		13.6	3.8	14.1	3.7	13.7	3.4
Rainwater 317																	14.3	3.4		
Rainwater GH									n/a		<12						14.7	3.3		

mean background	stdev background
14.24	1.924
background +2 stdev	
18.09	

	9/26/2000		7/11/2001		8/20/2001		9/10/2001		6/26/2002		8/15/2002		9/1/2002		6/18/2003		7/24/2003		9/10/2003	
mean TU	14.76	3.97	23.24	3.16	19.27	3.56	17.77	3.48	35.89	3.04	62.46	2.94	82.35	3.35	20.96	3.53	31.39	3.557	59.67	4.02
mean TU w/o bckgrnd	14.70	3.91	25.13	3.19	19.79	3.53	18.98	3.44	28.35	2.97	44.11	2.83	82.35	3.35	21.63	3.51	36.03	3.58	65.41	4.10
std dev	3.521		11.411		5.246		5.670		34.593		79.631		71.591		19.589		29.817		36.400	
min TU	11.4		11.7		11.8		9.4		9.82		6.4		<9.05		9.9		10.2		13.7	
max TU	20.1		58.9		34.8		41.3		108		203		189		118		118		136	
n	10		20		25		26		12		11		5		14		14		9	
background	11.9	0.707	n/a		18	n/a	16	n/a	9	n/a	12	n/a	9		14		14		14	
mean pCi/L	47.22		74.36		61.65895		56.88		114.83		199.87		263.52		67.06667		100.4343		190.93	

1 TU = 3.2 pCi/L

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