Vernal Pool Project Final Report: 2011

Nathan Byer

Introduction

An ephemeral wetland pool within the Anita C. Leight Estuary Center grounds has recently been the focus of recent study. The wetland area is best described as an ephemeral pool situated in a region of higher elevation in the forest. Its close proximity to trails makes it an interesting potential visitor attraction and a convenient subject for research studies. Although Estuary Center staff has done limited surveys of the area, it has not yet been the subject of official investigation and study.

Ephemeral wetlands have become an increasingly important topic for ecosystem-level research. In particular vernal pools have become a popular topic for study. However, there is some debate as to what exactly constitutes a vernal pool and what an ecosystem requires to sustain a vernal pool. The classification system proposed by Cowardin *et al* (1979) and interpreted by Ferren and Fiedler (1993) defines vernal pools as "seasonally flooded emergent wetlands of the palustrine system" (Cowardin et al 1979, Ferren and Fiedler 1993, Keeley and Zedler 1998). In addition, Keeley and Zedler (1998) propose that three key components must be understood in order to define any vernal pool habitat: the source of water, the duration of the wet and dry seasons of that pool, and the timing of those seasons. As such, they define vernal pools as seasonal wetlands that fill by precipitation during optimal temperature periods for plant growth, consequently go through a "waterlogged-terrestrial" stage, and finally experience an extended dry period (Keeley and Zedler 1998).

The study of ephemeral pools requires careful consideration of both the biotic and abiotic conditions of the area. Commonly studied abiotic factors include soil quality, water quality, rainfall, depth, volume, and area (Brooks and Hayashi 2002, Brown and Young 2005, Colburn 2008**,** Whigham and Jordan 2003). Biotic factors that can be studied generally involve species diversity and/or richness of plants and animals in and around the ephemeral pool area (Brown and Young 2005, Colburn 2008, Zedler 2003).

Methods

Study Site

The ephemeral pool lies along the left branch of the Discovery Trail at Anita C. Leight Estuary Center at an elevation of approximately 65 m (Figure 1). The area is between the Joppa Gravelly Sandy Loam and Beltsville Silt Loam soil series (USDA Natural Resources Conservation Service). Maryland Geological Survey geological maps of Harford County indicate that the area is in the Potomac soil series (Figure 9, MGS 1968). The forest surrounding the pool consists primarily of Nyssa sylvatica and Quercus prinus with an understory of Kalmia latifolia and Vaccinium corymbosum.

According to Anita C Leight Staff, the pool has been recorded in the park since 1996, when the estuary center was established, and most likely existed before that. In 2011, Anita C. Leight staff and associates observed the pool and noted that it held water from early April to mid-May. No amphibian life was observed during this period. From May through July, the pool area was dry, with very little evidence of water retention in the soil. The only features that differentiated the pool from the rest of the forest were the shallow depression, which was of slightly lower elevation than the immediately surrounding forest, and the nearly complete lack of vegetation within the pool area.

Soil Survey

Length and width lines were run across the area in order to divide the area into four quadrants. The area within 1.5 m radius of the intersection of these two lines was designated 'VPC' or 'Vernal Pool Center.' Similarly, the area outside of this area but within the estimated confines of the vernal pool was defined as 'VPO' or 'Vernal Pool Outside' and the area outside of the confines of the vernal pool was defined as 'VPF' or 'Vernal Pool Forest' (Figure 1). Three points were randomly selected in each zone by throwing a dart at a two dimensional diagram of the vernal pool. Two core samples were taken at each point; one sample was separated into upper (designated U) and lower (designated B) layers, while the other was kept intact. The samples were all weighed and placed in a drying oven at 60 degrees Celsius for 12 hours. They were then weighed again in order to give a soil moisture content value, and were then homogenized with a mortar and pestle. From these data, bulk density was calculated as well.

The 'U' and 'B' samples were taken to Maryland Geological Survey for Loss on Ignition (LOI) analysis, a test to determine the amount of organic carbon in the sample. The technique used was adapted from Storer (1984). Samples were placed into crucibles and weighed before heating and after one hour at 105 degrees Celsius. The hour long heating ensured that all or nearly all moisture was eliminated from the samples. Afterwards, samples were heated at 360 degrees Celsius for two hours, after which they were weighed again. These pre- and post-LOI weights were used to calculate %LOI values. In addition, approximately 10 µg each of Vanadium Oxide and each of the 'U' and 'B' soil samples were placed into small aluminum containers, which were then crimped and placed into sample vials. These sample vials were then analyzed for total nitrogen, carbon, and sulfur. The intact core samples (nine in total) were sent to the University of Massachusetts-Amherst soil labs for their standard soil test. This included tests for pH, buffer pH, extractable nutrients, extractable heavy metals, cation exchange capacity, and percent base saturation.

Vegetation Transects

Two transects were created to study plant diversity. Each transect ran for 50 m, and passed through the vernal pool with start and end points 25 m from the center of the pool. Each transect bisected two quadrants (Figure 2**)**. At every meter along each transect, all species of flora intersecting the vertical plane of that transect point were recorded. Additionally, every 5 m (excluding the center) a one meter by one meter square PVC pipe quadrat was used to estimate density of flora either to the left or right of that point. The decision to place the quadrat either to the left or right of each 5 m mark was made randomly with a coin flip (heads=left, tails=right). When placing the quadrat frame, one side was placed flush with the transect line, and was oriented so that the 5 m mark on the transect line coincided with the halfway point on that side of the frame. All plants rooted within the frame were counted and recorded.

Depth measurements

Depth measurements were taken every meter along the length and width lines on six dates: August 30 and September 1, 3, 10, 17, and 24. The length line was designated line A-B, where A and B are endpoints, and the width line was designated line C-D, where C and D are endpoints (figure 1). In total, 19 points on line A-B and 13 points on line C-D were measured for depth, including the endpoints. Throughout the course of early September, hurricane Irene and tropical storm Lee caused significant rainfall. In consideration of this atypical rainfall, data on rainfall for each day in August and September were collected for Abingdon, MD from weather.com as a point of comparison for the depth measurement data.

Insect survey

Insect samples were to be collected from nine 15 cm long by 15 cm wide by 10 cm deep soil samples. Three samples would be collected in each of the three zones described above: VPC, VPO, and VPF. The samples were to be sifted and searched for any insect life. Any insects found in each sample were to be placed in a killing jar. The killing jar consisted of ethyl acetate-soaked cotton swabs towards the bottom of the jar and a cardboard platform above the cotton so that insects would not become entangled in the cotton. Insects would then be placed in vials according to the location in which they were found for later identification.

Ground Penetrating Radar

The Maryland Geological Survey (MGS) conducted a Ground Penetrating Radar survey on the vernal pool area. This technique uses electromagnetic pulses to detect point source (like stones, small objects) and non-point source (such as layers of dense strata or mineral beds) underground disturbances. Although this technique does not indicate the type or classification of disturbance, it is useful for determining the existence of a disturbance and its approximate size.

Results

Soil Parameters

Soil moisture content values are reported in Figure 3. Values ranged from below 10% to approximately 50%. The highest moisture content was found in sample VPC-2U, and all upper samples (U) had higher moisture contents than the lower sample (B) taken from the same location (i.e. VPC-1U vs. VPC-1B).

The Maryland Geological Survey analyzed upper and lower soil samples for carbon, nitrogen, and sulfur. Most U soil samples had much higher nitrogen, carbon, and sulfur than their corresponding B samples (Table 1). Maryland Geological Survey results also included loss on ignition and total carbon percentages (Table 2). These two indicators were found to have a regression coefficient which is within the same range of results in Konen et al (2002) (Figure 4), since a conversion factor of 1.724 is often used to convert organic matter to total carbon (Nelson and Sommers, 1996).

The University of Massachusetts soil testing lab provided data on nutrients and pH. Results from the nutrient analysis can be found in Table 3. Iron and Aluminum levels were higher inside the pool than outside the pool, and were particularly high in the VPC (Vernal Pool Center) samples (Table 3). Soil pH values are reported in Table 4. Values ranged from 3.4-4.0, indicating that the soil in and around the pool is acidic.

Depth and Water Quality

During the months of August and September, the vernal pool area received approximately 30 inches (76.2 cm) of rainfall, primarily between August 28th and September 10th (Figure 5). The pool was first recorded as holding water on August 30th, following heavy rainfall from hurricane Irene (Figure 6). The maximum recorded depth of the pool (38.7 cm) was recorded on September 10th (Figure 6). This increase in pool depth corresponds to a spike in rainfall totals due to tropical storm Lee during the week of September 4th. Water quality criteria were also assessed. Total nitrogen and phosphorus values are presented in Table 5. A YSI water probe was also used to assess water quality criteria; results from the six YSI samples are presented in Table 6.

Vegetation

The plant transects indicated that there were generally fewer plant species in the pool compared to outside of the pool (Figure 7). Most of the plant species identified within 5 m of the center of the pool were hardwoods that were rooted outside of the pool itself. The primary tree species found by this method of sampling were Quercus coccinea, Nyssa sylvatica, and Quercus prinus, whereas the primary shrub and understory plants were Vaccinium corymbosum and Kalmia latifolia.

Quadrant plant sampling indicated that rooted plants may be aggregated towards the south and west areas around the vernal pool, with very few plants rooted towards the north and east (Figure 8). The results from this sampling method also indicate that there are very few plants rooted inside the pool (Figure 8). The primary plants found through this method of sampling were Vaccinium corymbosum and Lycopodium dendroideum, which, when present, tended to dominate the understory.

Insects and other biota

Insect sampling by the spade and shovel method was found to be ineffective for this study site. All samples taken (both inside and outside of the pool) lacked soil insects, and consisted of a dense, tenacious root layer permeating throughout organic soil. Other potential sampling methods will be suggested below. Although the insect sampling was unsuccessful, 4-6 anurans were found in the pool between the months of August and November. These anurans were identified as Green Frogs (Lithobates clamitans).

Ground Penetrating Radar Findings

Ground penetrating radar surveying revealed two distinct types of disturbances in the strata. The GPR results did not specifically indicate what each disturbance was, but indicates instead the approximate location of each disturbance. The first type was between two and three feet below the surface, and consisted primarily of point sources. These point sources are most likely rocks, large tree roots, or other subterranean debris. The second type was between six and seven feet, and consisted of non-point sources. These could potentially be mineral deposits, large stones, or potentially any other large items or debris that may be beneath the vernal pool surface.

Discussion

<u>Can our pool be considered a vernal pool?</u>

Based on the basic definitions of a vernal pool set forth by Keeley and Zedler (1998) and Ferren and Fiedler (1993), the pool at Anita C. Leight Estuary Center can be considered to be a vernal or ephemeral pool, as it experiences a prolonged dry period during the winter, experiences a likely quite variable water-logged stage, and retains water for at least three months. In addition, some preliminary data on the three criteria involved with first studying vernal pools – namely the source of water, the duration of wet and dry seasons, and the timing of those seasons – have been collected. Rainfall and depth data suggest that the pool fills exclusively from rainfall in the summer and drains by mid-spring for a hydroperiod of approximately 4-5 months. However, the weather patterns for the months of August and September were very atypical, with approximately 32 inches of rain over a two month period (Figure 5). Since large amounts of precipitation from storms can cause dramatic increases in pool hydroperiod, the hydroperiod observed during this study period may not be representative of other, drier years. Further research must be conducted on the hydrology of this pool during years with more typical weather patterns.

The pool also does appear to host amphibian life, which is often considered a crucial criterion for determining vernal pool and forest pool health and biological activity (Calhoun et al 2003). Though no breeding activity was observed (in the form of anurans in amplexus or egg masses), the observed presence of green frogs does suggest the potential for breeding activity in the future. Though green frogs are not considered indicator species for vernal pools, their presence at this pool may indicate the potential for this pool to be used by facultative species, which use ephemeral pools for food, water, shelter, or breeding but may use other habitats if needed (Brown and Jung 2005).

Potomac series and lignite mining

Soil data indicate several unifying features of the soil in the vernal pool area: low pH, high Aluminum concentrations, high Iron concentrations, and relatively high percent Carbon. High Aluminum concentrations in conjunction with low pH can cause severely limited plant productivity, suggesting that the poor plant growth in the vernal pool may be due to phytotoxic conditions (Kochian 1995). These soil characteristics could potentially be explained by the presence of two common materials in Potomac series soils: lignite and siderite (Darlene Wells, Pers. Comm). Lignite is a type of fuel, similar in many ways to coal, that can have carbon content as high as 35% (Darlene Wells, Pers. Comm, Mackie 1861). Lignite mining often results in phytotoxic conditions, such as low pH and high metal concentrations (Schaff and Hüttl 2006), suggesting that the vernal pool area may have been involved in lignite mining in the past. Siderite, a mineral of iron carbonate, may explain the high iron and the subterranean disturbances located by the GPR (Darlene Wells, Pers. Comm.).

Recommendations for Future Studies

Much of the work for this project was to establish baseline data for future studies on this vernal pool, and to potentially create protocols to use for studying this and other vernal pools or ephemeral wetlands. Thus, there are many different research topics that could be covered at this pool. The most pressing of these potential studies would involve assessing the hydroperiod and physical characteristics of the pool during a year with more typical rainfall patterns. The large storms that occurred in August and September brought about unusual amounts of concentrated rainfall, and understanding the physical parameters of the pool during a year with fewer large, concentrated weather systems could prove to be interesting. A study of these physical characteristics would ideally take more water and soil samples than were taken in this study, primarily to increase sample size and better recognize physical trends in this area. Physical excavation of the site using a backhoe or similar tool may provide valuable information about the soil morphology of the area, as well as potentially provide answers as to what may be under the pool.

Further efforts should be made to study biota in this area as well. A more exhaustive plant survey may involve more transects passing through or around the pool. In regards to invertebrate sampling, the spade sampling method appeared to be largely ineffective for this area. Potential alternate sampling methods for soil invertebrates include using a modified Berlese separator (Dietrick et al 1959) or pitfall traps (Brooks et al 2003). The observed presence of amphibians in the pool also means that future work should be done to inventory and assess amphibian utilization of the pool when inundated.

In addition, delving further into the history of the site may provide useful information about the history of both this vernal pool and of the surrounding area. Historical land use of the pool may provide clues as to whether the pool in anthropogenic or natural in origin. Applying all of the above with GIS technology will allow the pool to be mapped in relation to the surrounding area as well.

Acknowledgements

First, I would like to thank internship coordinator Kathy Baker-Brosh for many months of coordination and planning assistance. Without your help and guidance, much of the planning for this difficult yet interesting project would have been overwhelming. I would also like to thank

Kriste Garman, Donald McKnight, and Estuary Center staff for affording me the opportunity to work on this project, as well as for ordering supplies, assisting with storage of supplies, and overall allowing me to use the facilities. Darlene Wells, Richard Ortt, David Drummond, and the Maryland Geological Survey provided invaluable support for this project, particularly in soil sample processing and GPR; correspondence with Darlene Wells also played heavily in much of the planning and implementation of this project. Jeffrey Campbell provided GIS recommendations which could not be implemented for this project, but will prove to be invaluable for future projects. Last but not least, I would like to thank my fiancée Ashley Stansbury, family, and friends for field assistance and support during this project.

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Tables and Figures

Tables

Sample ID	Nitrogen (% dry weight)	Carbon (% dry weight)	Sulfur (% dry weight)
VPC-1U	0.542	7.970	0.123
VPC-1B	0.124	1.806	0.033
VPC-2U	1.286	21.901	0.270
VPC-2B	0.172	2.801	0.038
VPC-3U	0.879	14.999	0.182
VPC-3B	0.206	3.279	0.039
VPO-1U	0.525	8.915	0.096
VPO-1B	0.082	1.211	0.018
VPO-2U	0.717	12.591	0.107
VPO-2B	0.079	1.432	<0.001
VPO-3U	0.987	19.322	0.141
VPO-3B	0.156	3.722	0.054
VPF-1U	0.660	14.727	0.088
VPF-1B	0.117	3.824	0.016
VPF-2U	1.331	31.036	0.103
VPF-2B	0.263	8.396	0.035
VPF-3U	0.553	15.152	0.066
VPF-3B	0.103	2.868	<0.001

Table 1: Nitrogen, Carbon, and Sulfur values for upper and lower soil samples (courtesy of MGS). Note higher % dry weight values for upper vs. lower samples.

Sample ID	Loss on Ignition (%)	Total Carbon (% dry weight)
VPC-1U	13.76287	7.970
VPC-1B	5.235341	1.806
VPC-2U	23.00117	21.901
VPC-2B	5.77735	2.801
VPC-3U	21.75935	14.999
VPC-3B	5.859367	3.279
VPO-1U	15.00636	8.915
VPO-1B	2.740992	1.211
VPO-2U	19.27864	12.591
VPO-2B	2.621277	1.432
VPO-3U	26.39304	19.322
VPO-3B	4.675892	3.722
VPF-1U	21.91077	14.727
VPF-1B	2.69105	3.824
VPF-2U	47.14027	31.036
VPF-2B	8.099371	8.396
VPF-3U	17.96939	15.152
VPF-3B	3.721716	2.868

Table 2: Loss on Ignition and Total Carbon values for soil samples (courtesy of MGS).

	Nutrient Concentrations (ppm)											
Plot type	P	K	Ca	Mg	NO_3	B	Mn	Zn	Cu	Fe	S	Al
VPC-1S	14	91	77	48	0	0.7	1.9	4.2	0.9	62.4	30.8	526
VPC-2S	11	92	62	36	0	0.6	1.5	7	0.8	41.3	30.3	465
VPC-3S	10	130	49	30	0	0.6	1	3.3	0.8	36.7	32.7	407
VPO-1S	8	56	76	51	0	0.6	1.8	5.9	0.8	61.3	17	301
VPO-2S	9	84	100	81	0	0.6	3.2	3.9	0.8	15.9	18.6	190
VPO-3S	8	76	43	21	0	0.5	0.5	4.5	0.8	23.1	25.2	284
VPF-1S	8	81	74	37	0	0.6	2	7	0.8	20.8	12.6	56
VPF-2S	8	66	420	92	0	0.5	13.5	3.3	0.8	5.2	18.5	32
VPF-3S	6	49	129	50	0	0.5	4.4	5.3	0.8	22.3	15.4	54

Table 3: Nutrient concentrations for core samples sent away to University of Massachusetts- Amherst. Note higher Aluminum and Iron values inside vernal pool (VPC and VPO) vs. in the forest around the vernal pool (VPF).

Plot type	pH
VPC-1S	3.9
VPC-2S	3.9
VPC-3S	3.9
VPO-1S	3.8
VPO-2S	3.8
VPO-3S	4
VPF-1S	3.5
VPF-2S	3.6
VPF-3S	3.4

Table 4: pH values for core samples sent away to University of Massachusetts- Amherst. All samples have a pH ≤ 4.

Sample ID	TP (mg P/L)	TN (mg N/L)
VERNAL 1	0.0885	1.60
VERNAL 2	0.0925	1.92
VERNAL 3	0.0992	1.76

Table 5: Total Phosphorous and Total Nitrogen values for three samples taken when pool was inundated.

YSI Sample #	Temperature (c)	Salinity	pH	DO (%)	DO (mg/L)	conductivity (micro-S)	sp. Conductivity (micro-S)
1	20.9	0.02	8.12	22.8	2.05		
2	20.6	0.02	8.11	20	1.8		
3	20.7	0.02	8.1	15.8	1.42	44.6	48.1
4	20.8	0.02	8.1	20.8	2.11	44.6	48.3
5	20.4	0.02	8.09	19.3	1.74	44	48.2
6	20.3	0.02	8.09	17.1	1.5	43.6	47.8

Table 6: Water quality values for six samples taken when pool was inundated. Note low dissolved oxygen values.

Figures

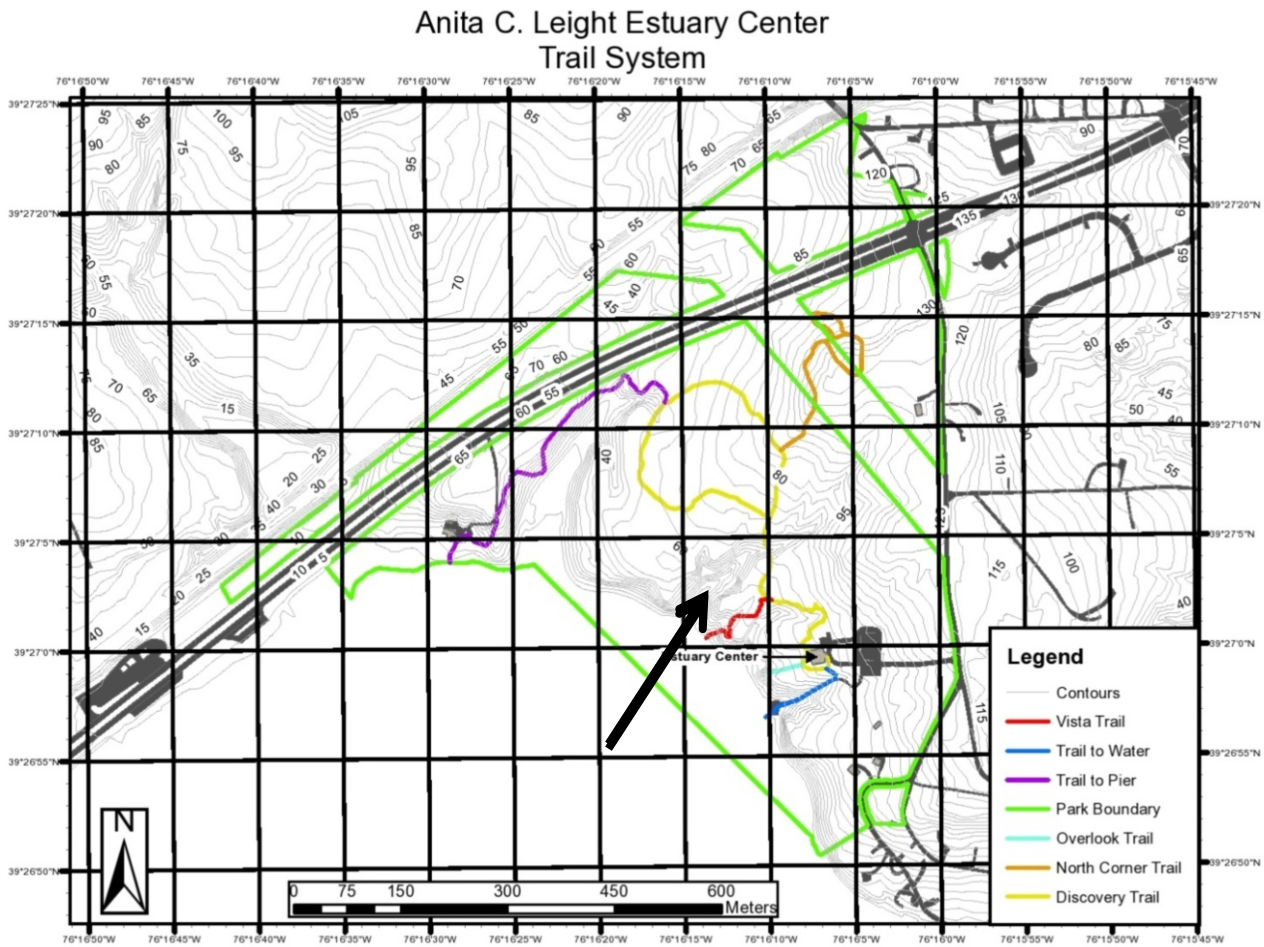

Figure 1: Elevation and Trail map of Anita C. Leight Estuary Center. The arrow indicates the approximate location of the ephemeral pool.

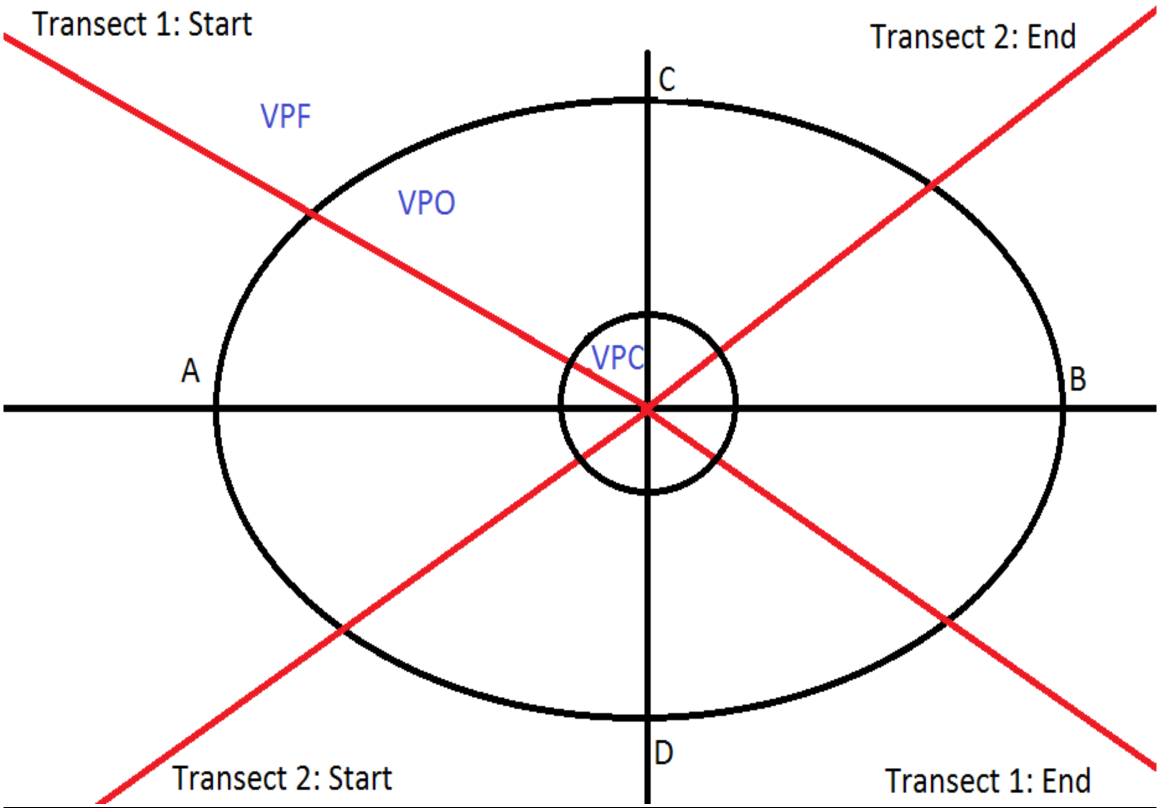

Figure 2: Diagram of organization of regions (VPC, VPO and VPF) of pool. Red lines indicate vegetation transects.

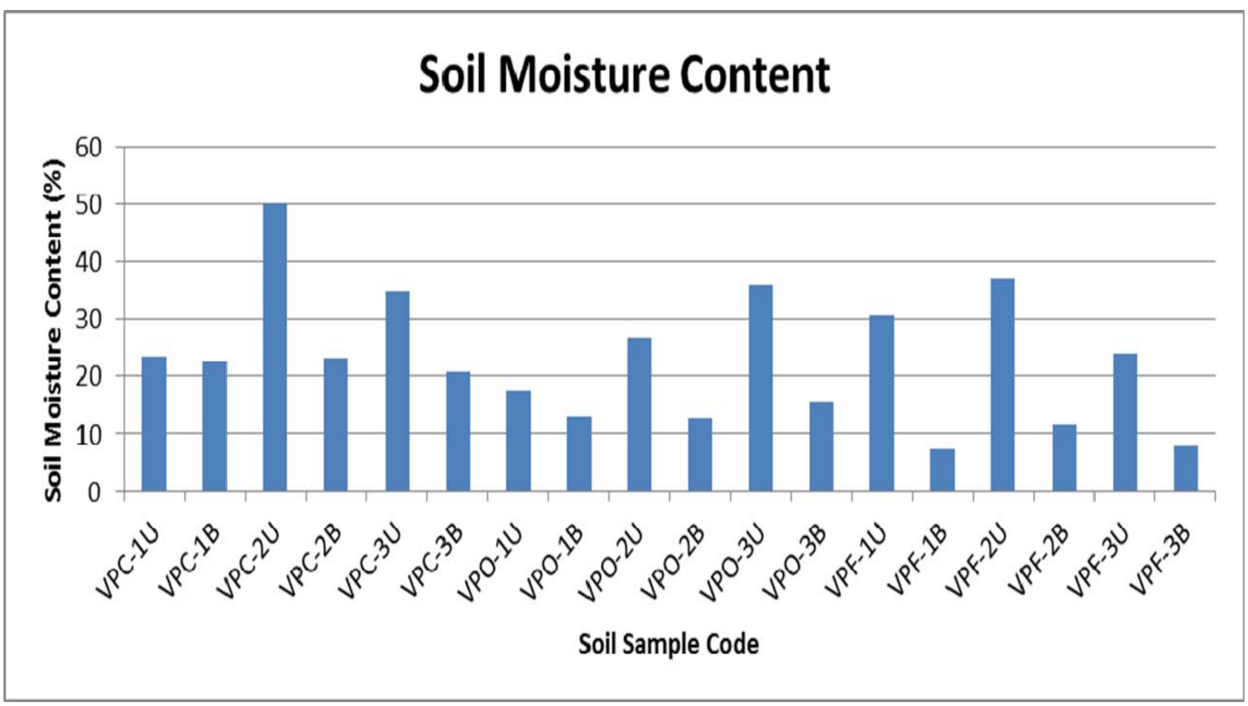

Figure 3: Soil moisture contents for upper and lower soil samples.

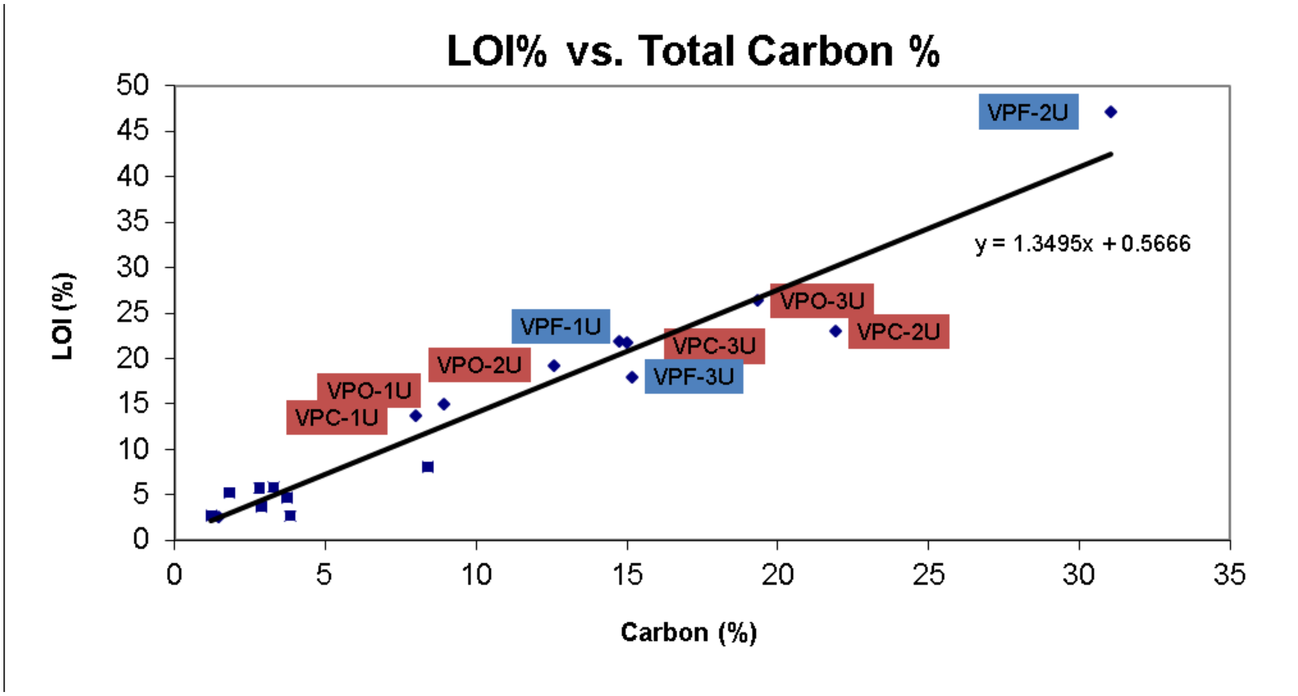

Figure 4: Loss on ignition vs. total carbon values for upper and lower core samples. Red tags represent upper soil samples from inside the pool, and blue tags represent upper soil samples from outside the pool. Note close relationship between LOI % and Total Carbon %.

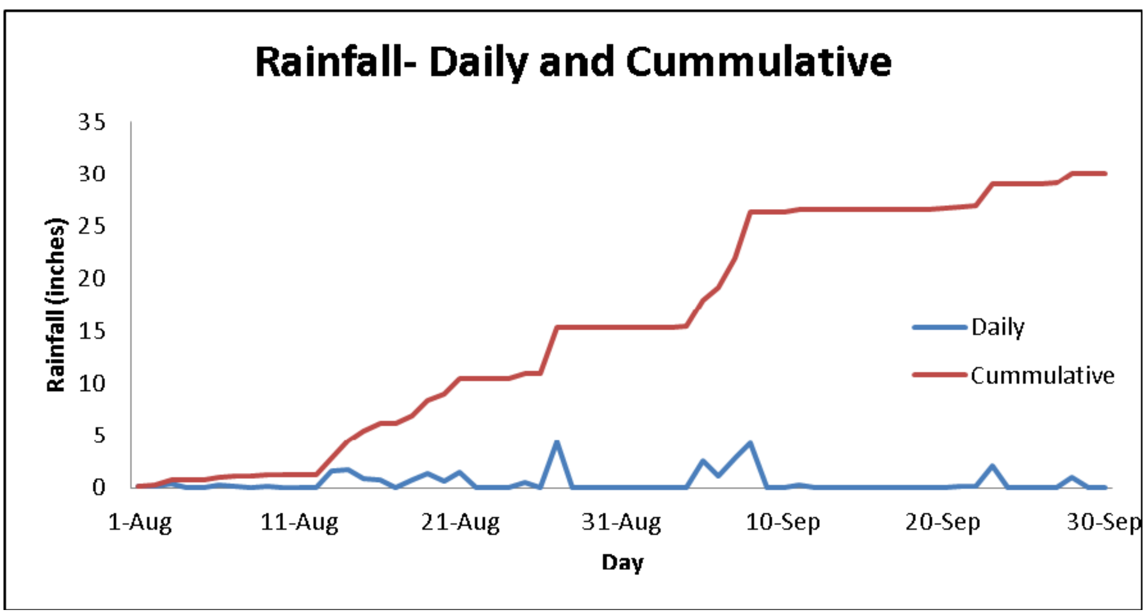

Figure 5: Rainfall totals (daily and cumulative) for the months of August and September. Rainfall totaled approximately 32 inches over these two months.

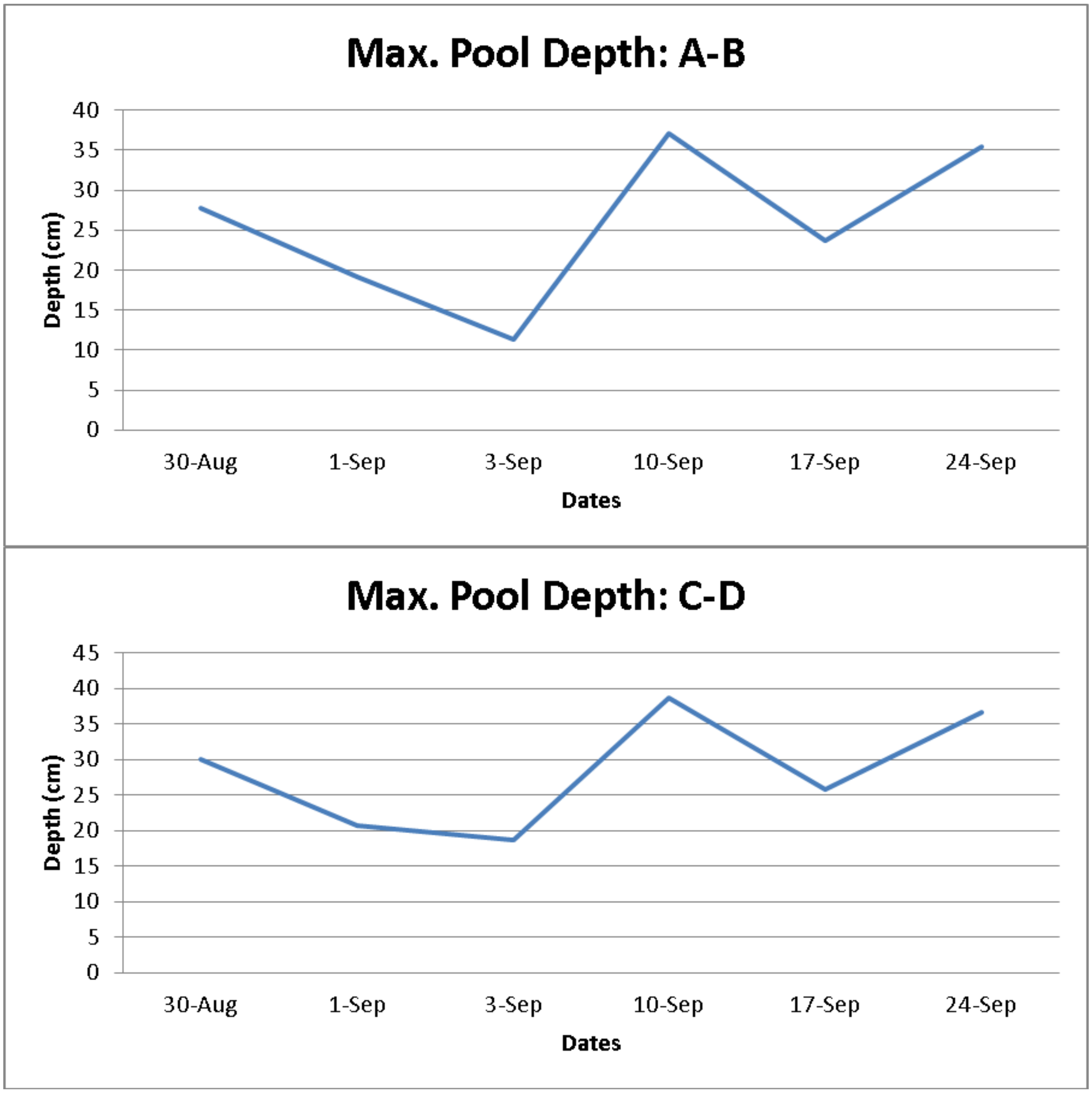

Figure 6: Maximum pool depths along length transect A-B and width transect C-D. Spikes in pool depth appear to be caused solely by rainfall (Figure 5).

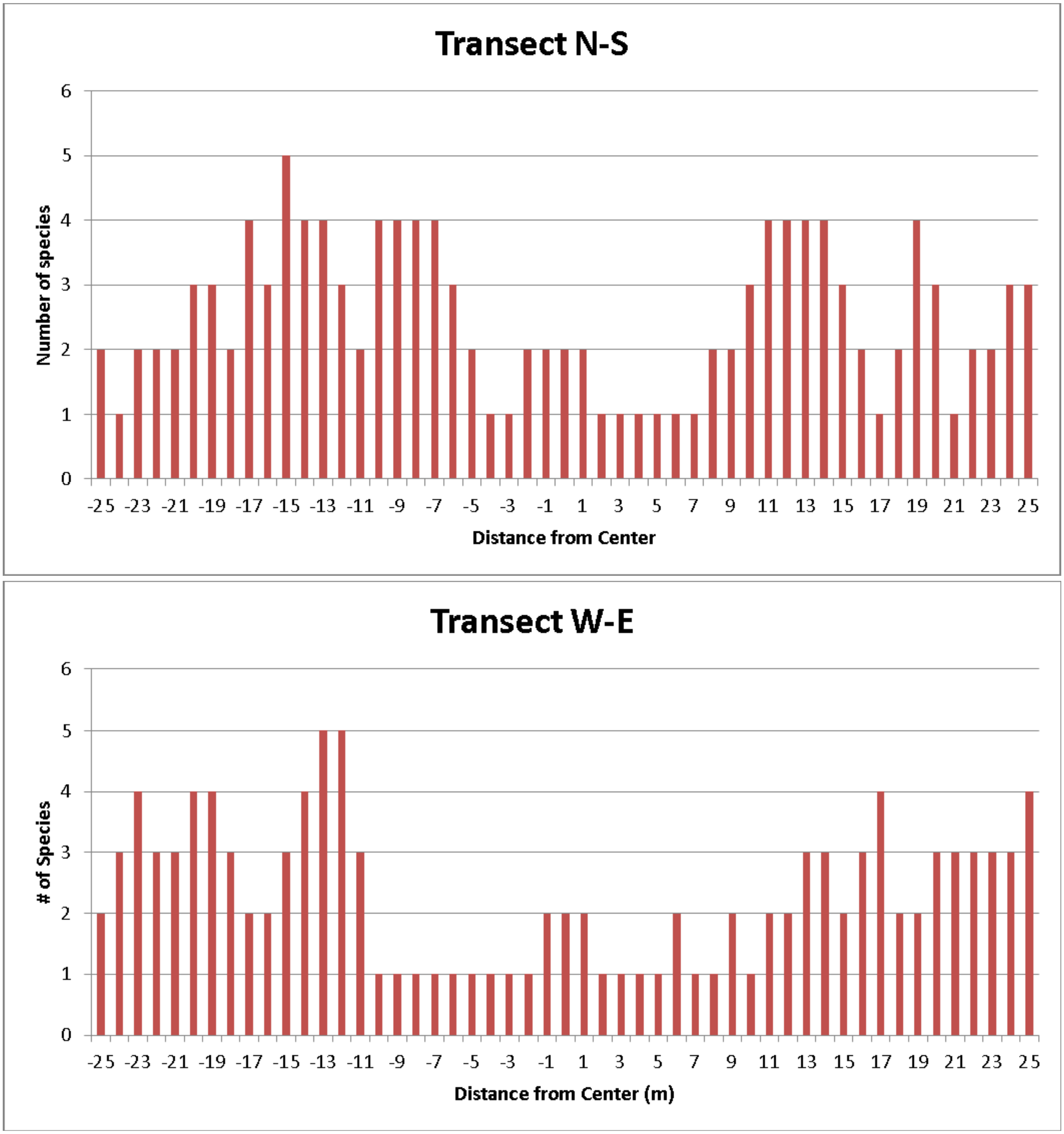

Figure 7: Number of plant species along N-S and E-W transects. Fewer plant species were found towards the center of the pool (within 5 m of the center) compared to the area outside of the pool (more than 5 m from center).

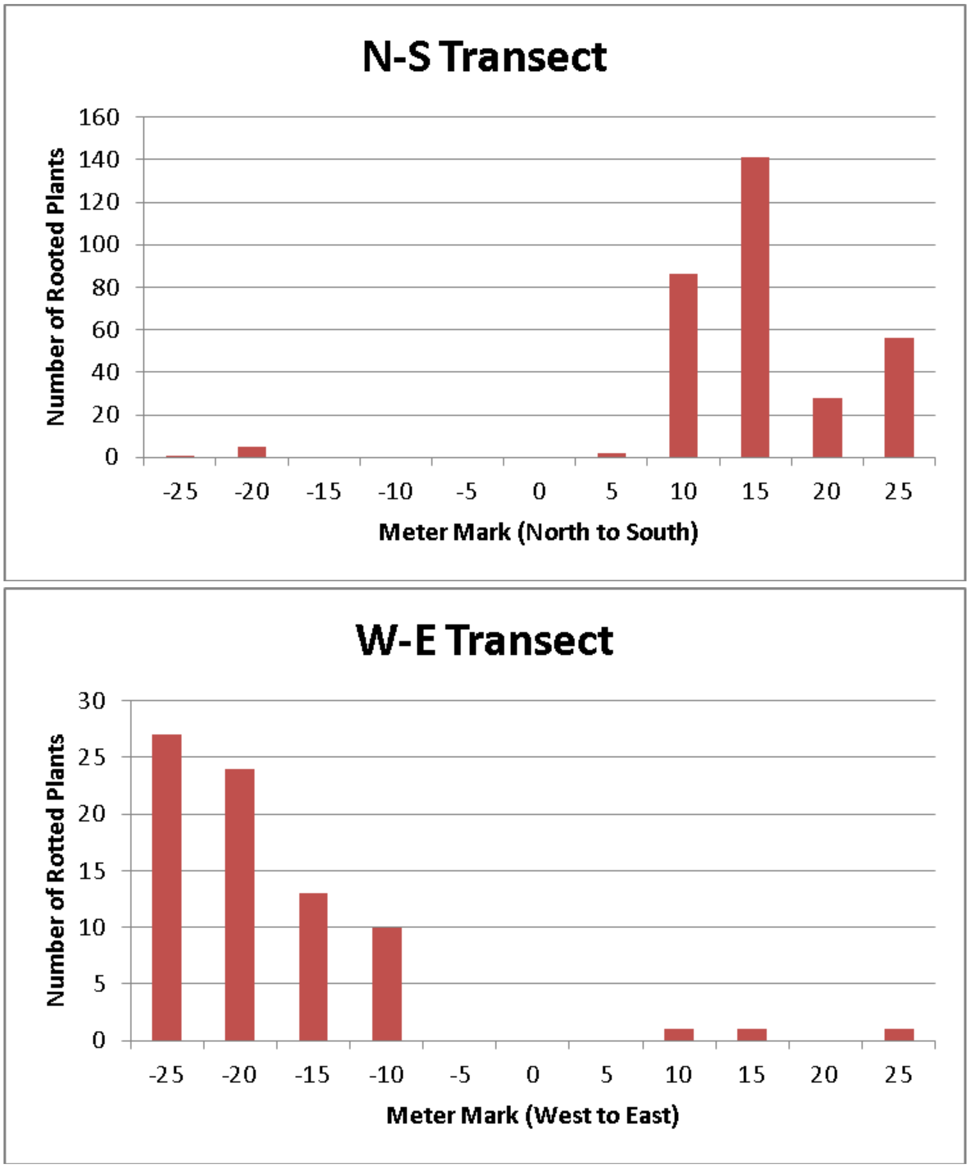

Figure 8: Number of rooted plants located using quadrat sampling along the N-S and W-E transects. Note larger numbers of rooted plants in West and South directions than North and East directions.

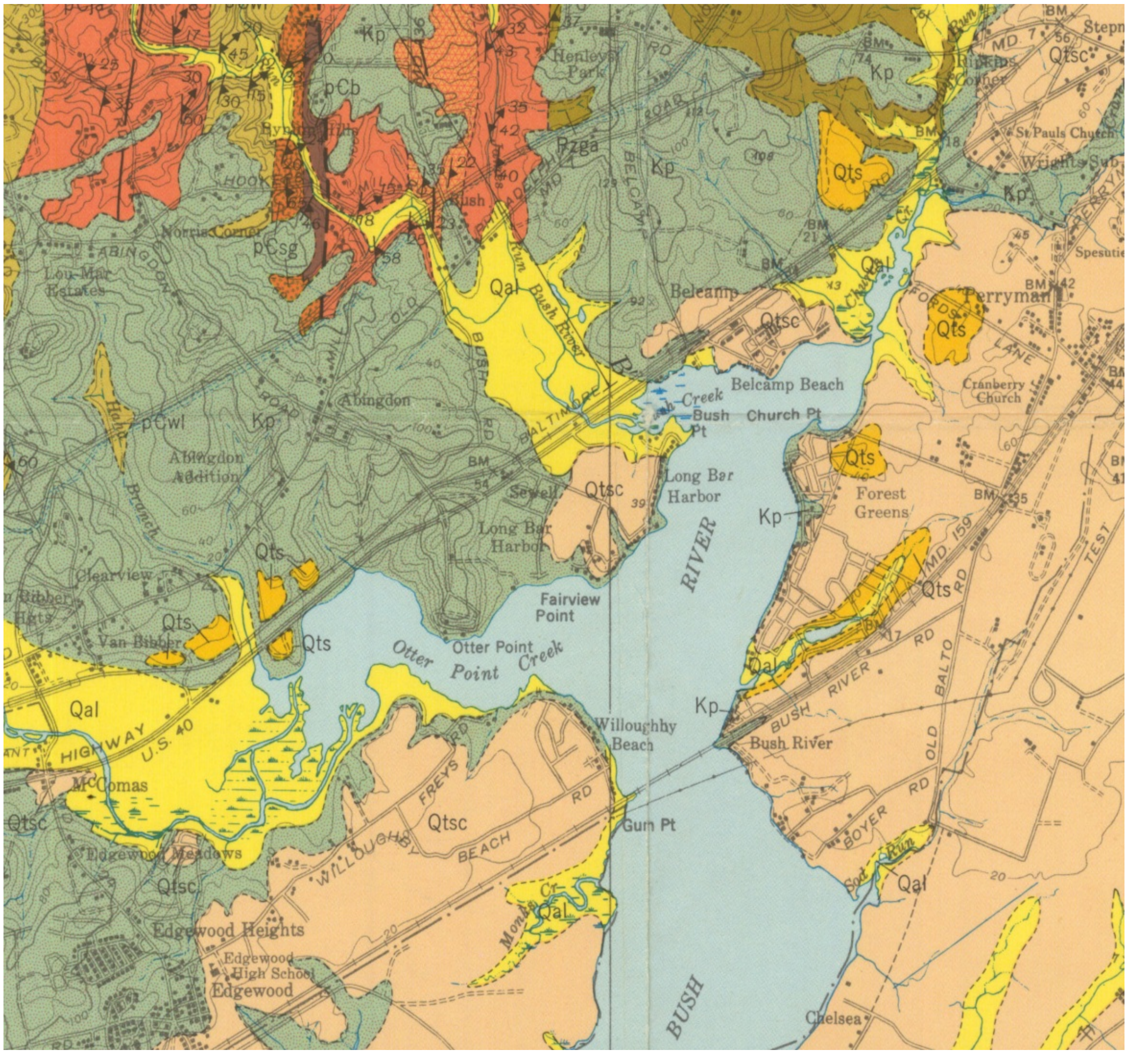

Figure 9: Map of the Bush River-Abingdon area, as taken from MGS Bulletin 32. Otter Point Creek and Anita C. Leight Estuary Center are located in the Potomac group soil series, as denoted by the green-colored regions.