Final Project Report

KASKASKIA RIVER BASIN FEASIBILITY STUDY SUPPORT
Agreement No. KRBFS1701

Submitted to: the State of Illinois Environmental Protection Agency Bureau of Water
By: HeartLands Conservancy (Mary Vandevord, President & CEO)

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PROJECT PURPOSE

The Kaskaskia River Basin feasibility study will examine solutions to critical problems for identification in a comprehensive watershed plan. The plan will help to restore, preserve and protect the Kaskaskia River Basin (Appendix A) by developing and providing new techniques and innovative approaches to some of the Kaskaskia Watershed's most critical issues. This project October 2016 – June 2017 was the first step in a multi-year process to develop the study.

Specific issues include: enhancing the Kaskaskia River as a transportation corridor; improving water quality within the basin; enhancing, restoring, and preserving habitat for plants and wildlife; increasing economic and recreational opportunities; and reducing flood impacts.

The project was included as a match to the US Army Corps of Engineers Kaskaskia River Basin Feasibility Study : http://www.mvs.usace.army.mil/Missions/Recreation/Kaskaskia-Watershed/

The original schedule of this project was October 15, 2016 to October 2018; however, IEPA terminated the contract due to financial complications. This early termination did not allow enough time to complete all tasks in the project.

I. IDENTIFICATION OF LANDSCAPE PRACTICES AFFECTING WATER QUALITY IN THE KASKASKIA RIVER BASIN

The 2016 Illinois Integrated Water Quality Report and Section 303(d) List reports 1,192 miles of rivers/streams and 43,140 acres of lakes/ponds within the Kaskaskia watershed that are failing to meet their designated uses due to multiple causes (Table 1). The predominant impaired designated use for rivers and streams is aquatic life, and the primary causes of impairments are excessive total phosphorus and sediments, as well as insufficient dissolved oxygen (Table 2). For lakes and ponds, aesthetic quality and fish consumption are the predominant impaired designated uses, and excessive suspended sediments and mercury are the primary causes of impairment. The National Great Rivers Research and Education Center (NGRREC) made a more thorough examination of water quality data for the Silver Creek watershed, located in the Lower Kaskaskia watershed, as part of our contribution to HeartLands Conservancy's 604(b) and 319(h) grants from the Illinois EPA. Results from that examination of data indicated that Silver Creek was primarily impacted by excessive sediment eroding into the stream network, along with sediment-related pollutants such as total phosphorus.

Sediment erosion originates from primarily two sources: 1) sheet and rill erosion from agricultural land, and 2) streambank erosion. Results from the 2015 Conservation Transect Survey conducted by the Illinois Department of Agriculture reported that four counties located totally or partially within the Kaskaskia watershed ranked among the top 10 counties in the state of Illinois with soil loss exceeding the NRCS-established tolerable (T) level by more than 200%. There was evidence of ephemeral erosion in 3 to 45% of the fields in the 20 counties that are located totally or partially within the Kaskaskia watershed. Simultaneously, no-till conservation practices for corn production in these same counties ranged from only 0 to 20.1%. Obviously, there is an opportunity to increase the use of conservation tillage practices in all counties located within the Kaskaskia watershed. Use of no-till and other conservation tillage practices will reduce sedimentation and total Phosphorus in rivers and streams in the Kaskaskia watershed by protecting soils from erosion, and also reduce intense runoff events and flooding by increasing the infiltration rate of rainfall into the soil.

Table 1. Numbers of impaired water bodies for each designated use for the Kaskaskia River watershed.

Designated Use	**Rivers/Streams**	**Lakes/Ponds**	**Total**
Aquatic Life	164	4	168
Fish Consumption	25	14	39
Primary Contact Recreation	10	0	10
Aesthetic Quality	7	22	29
Public and Food Processing Water Supplies	5	2	7
Total	211	42	253

Table 2. List of causes of impairments for rivers/streams and lake/ponds within the Kaskaskia River watershed.

Causes (Rivers/Streams)	**Rivers/Streams**	**Lakes/Ponds**	**Total**
Phosphorus (Total)	57	6	63
Oxygen, Dissolved	39	0	39
Sedimentation/Siltation	29	0	29
Total Suspended Solids (TSS)	12	16	28
Mercury	15	13	28
Polychlorinated biphenyls	10	1	11
Fecal Coliform	10	0	10
Cause Unknown	7	0	7
Manganese	6	0	6
Iron	6	0	6
pH	3	2	5
Temperature, Water	4	0	4
Atrazine	2	1	3
Sludge	3	0	3
Terbufos	1	2	3
Chloride	2	0	2
Simazine	1	1	2
Copper	1	0	1
Bottom Deposits	1	0	1
Turbidity	1	0	1
Endrin	1	0	1
Total	211	42	253

II. LAND USE PRACTICE PROJECTIONS IN 100-YEAR FLOODPLAIN BASED ON PRECISION CONSERVATION PLANNING

Methodology

The Agricultural Conservation Planning Framework (ACPF) Tool was developed by the USDA Agricultural Research Service in order to assess which conservation practices are most suitable for implementation in a watershed, as well as guidance on where to place conservation practices on the landscape. The tool uses LIDAR data and ArcGIS software to generate a flow network for the targeted HUC12 watershed. Comprehensive crop and land use records from the National Agricultural Statistical Service (NASS) are combined with the detailed flow network and other geographical landscape features to determine the most appropriate types and locations for specific land conservation practices. The ACPF tool was applied to selected locations within the larger Kaskaskia watershed. The Plum Creek Watershed was used as the initial watershed because it consists of a single HUC12-size watershed (HUC 071402020902) that connects directly to the main stem of the lower Kaskaskia River. Furthermore, it has been identified by the IEPA as being impaired for dissolved oxygen, sedimentation/siltation, total phosphorus, manganese, and habitat alterations—impairments that are typical for most of the subwatersheds within the Kaskaskia River basin (Fig. 1). Additionally, the Plum Creek watershed is located entirely within Washington County which ranked near the bottom of all counties in Illinois for use of no-till crop production and near the top of all counties for the use of conventional tillage. Therefore, the Plum Creek watershed was a good candidate for evaluating the need for conservation practices.

Results

Table 3 lists the types and quantities of conservation practices recommended by the ACPF tool. Output from the ACPF tool should be used as the first step in conservation planning rather than an exact checklist. For example, the ACPF tool determined that there are 14 potential locations for nutrient removal wetlands in the Plum Creek watershed (Table 3 and Fig. 2). The total area that would be required for the nutrient removal wetlands is 46 acres with 127 acres of surrounding buffer area. The nutrient removal wetlands could potentially receive drainage from 3,965 acres. The ACPF tool does not consider what land management practices are currently being applied to these potential nutrient removal wetland areas, nor is it able to know landowners' attitudes or receptiveness to implementing the recommended conservation practice, and therefore, it is highly unlikely that all of these wetlands will be constructed. However, the ACPF recommendations can serve as a guide to conservation districts on where to target state and federal conservation contracts so that they have the greatest beneficial impact on water quality.

Other conservation practices considered by the ACPF tool include: 1) contour buffer strips, 2) grass waterways, 3) water and sediment control basins (WASCOB), 4) riparian zone restoration, including stream bank stabilization, and 4) drainage management, including bioreactors (Table 3). Just as with nutrient removal wetlands, the ACPF output for these conservation practices should be used as a guide on what types of conservation practices to use and where to place them. It is a first approximation and needs to be followed-up with considerable on-the-ground evaluation. For example, drainage management practices depend on the actual existence of tile drainage, but the tool does not know if actual tile drainage has been installed in these areas. The ACPF tool is only able to determine whether the landscape is a candidate for drainage management based on slope and soil type conditions. However, given the entirety of the Plum Creek watershed, the ACPF output shows the locations and areas where multiple conservation practices could have the greatest benefit for protecting soils from erosion and for keeping nutrients and sediments out of runoff and drainage waters. The greatest drawback to using the ACPF tool is the amount of time required to develop a detailed and accurate flow network based on LIDAR data, but that step is critical to tools ability to identify which types of conservation practices to use and where to place them on the landscape.

After using the ACPF tool to evaluate the Plum Creek watershed, we applied the tool to the Lower Silver Creek watershed in St. Clair County, which is currently part of Heartlands Conservancy's 604(b) grant to develop a watershed-based plan. Silver Creek is located in the lower Kaskaskia watershed and empties into the Kaskaskia River near New Athens. There are six HUC12s in the Lower Silver Creek watershed. As of June 30, a detailed flow network has been developed for four of these HUC12s. The remaining two HUC12s are scheduled to be completed by August 2017.

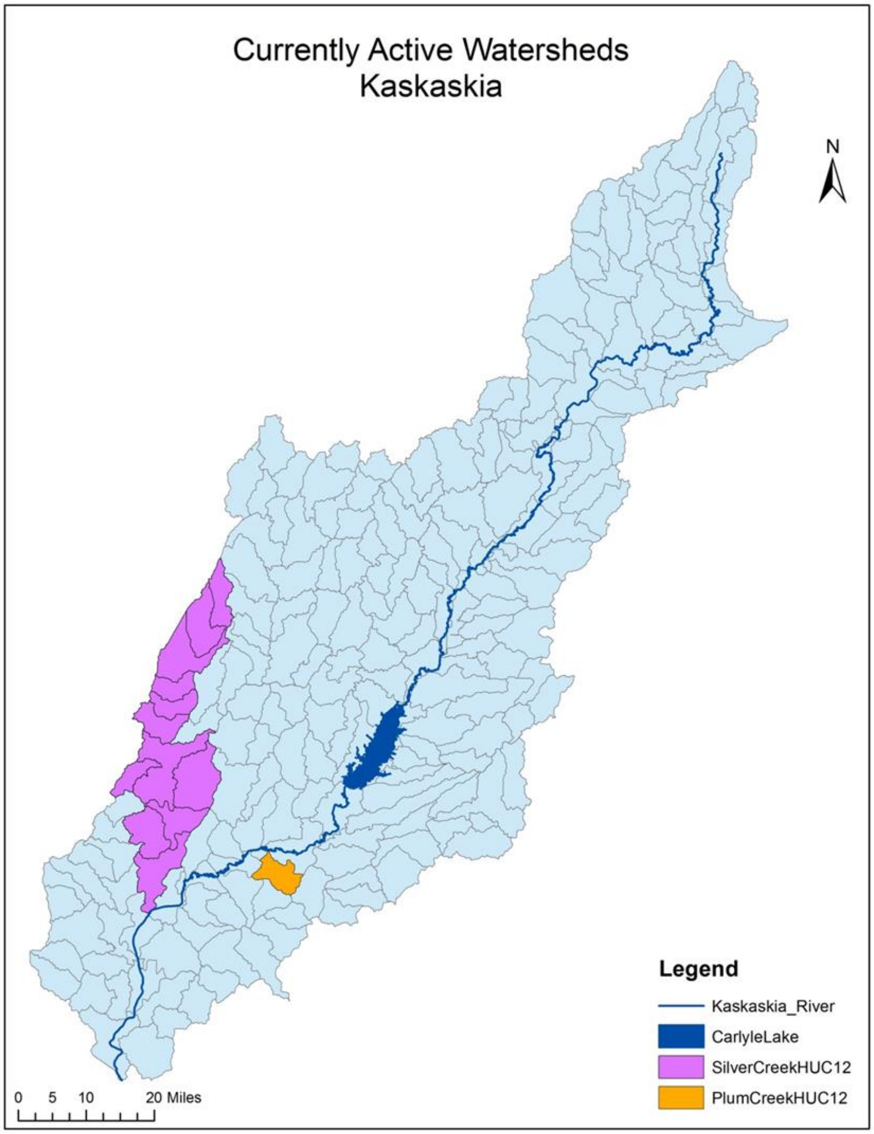


Fig. 1. Locations of Plum Creek and Silver Creek watersheds within the Kaskaskia River basin.

Table 3. List of conservation practices recommended by the Agricultural Precision Planning Framework (ACPF) tool for the 15,120 acre Plum Creek watershed (HUC 071402020902).

Type of Conservation Practice	**Quantity**
Nutrient Removal Wetlands	
Number of wetlands	14
Total area of wetlands (acres)	46
Total area of wetlands plus buffers (acres)	127
Total area draining into nutrient removal wetlands (acres)	3,965
Contour Buffer Strips	
Number of contour buffer strips	29
Total area contour buffer strips (acres)	7.7
Grass waterways	
Total length of grass waterways (ft)	22,111
Water and Sediment Control Basins (WASCOB)	
Number of WASCOBs	21
Total area of WASCOB basins when filled (ft^2)	3,647
Riparian Areas	
Number of Critical Zone segments (CZ)	6
Number of Multi Species Buffers segments (MSB)	28
Number of Stiff Stemmed Grasses segments (SSG)	41
Number of Deep Rooted Vegetation segments (DRV)	59
Number of Stream Bank Stabilization segments (SBS)	106
Drainage Management	
Number of drainage management areas	219
Total Area drainage management fields (acres)	3,800
Bioreactors	79

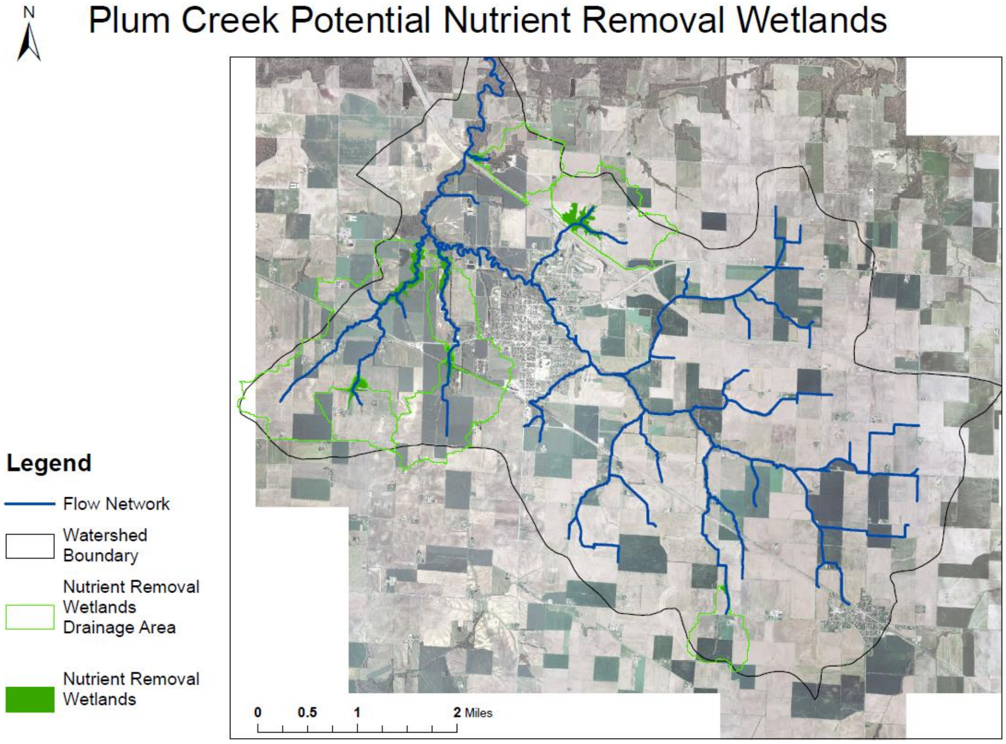


Fig. 2. Location of 14 nutrient removal wetlands (shown as bright green areas) recommended by the ACPF tool for the Plum Creek watershed.

III. KASKASKIA RIVER BASIN FEASIBILITY STUDY: Carlyle Lake water quality monitoring

Methodology

In general, water quality in reservoirs constructed on the main channel of rivers reflects the landscape management practices in the watershed upstream from the reservoir. With that in mind, NGRREC committed time and resources to monitoring water quality in Carlyle Lake located between the Middle and Lower sections of the Kaskaskia watershed. Five boat-based sampling excursions were conducted at 10 sites on the lake on 6/6/2016, 6/23/2016, 7/28/2016, 10/28/2016, and 5/21/2017 (Fig. 3). The 10 sampling sites were picked randomly from three depth profiles consisting of shallow, (S1, S2, S3), medium (M1, M2, M3, M4), and deep (D1, D2, D3). At each of the 10 sites, water samples were collected from the surface, mid, and deepest depths using a Van Dorn sampler. Simultaneously, NGRREC collaborators from Saint Louis University (SLU) collected sediment samples from the bottom of the lake using a Petite Ponar sampler. Actual sample collection depth depended on the overall depth at each of the sites on the actual date of sample collections. For example, sample depths on the 5/21/2017 excursion were much deeper than the other sampling dates due to extremely high flow conditions on the Kaskaskia River (Appendix B). Discrete water samples were analyzed for nutrients, suspended sediments, and dissolved organic carbon at the NGRREC Environmental Chemistry Laboratory at the Jerry F. Costello Confluence Field Station. Simultaneously, an Exo2 multi-parameter sonde was deployed at each site to collect a suite of standard water quality parameters including temperature, specific conductance, dissolved oxygen, turbidity, fluorescing dissolved organic matter (fDOM), chlorophyll, and bluegreen algae. In addition to boat-based sampling, a Great Rivers Ecological Observatory Network (GREON^{sm}) buoy was deployed on the lake during summer 2016. The GREON buoy contains an Exo2 multi-parameter sonde and a SUNA nitrate sensor, but for this report, we focused on continuous orthophosphate data collected with a Cycle-P orthophosphate analyzer that was added to the GREON buoy from May to June of 2016.

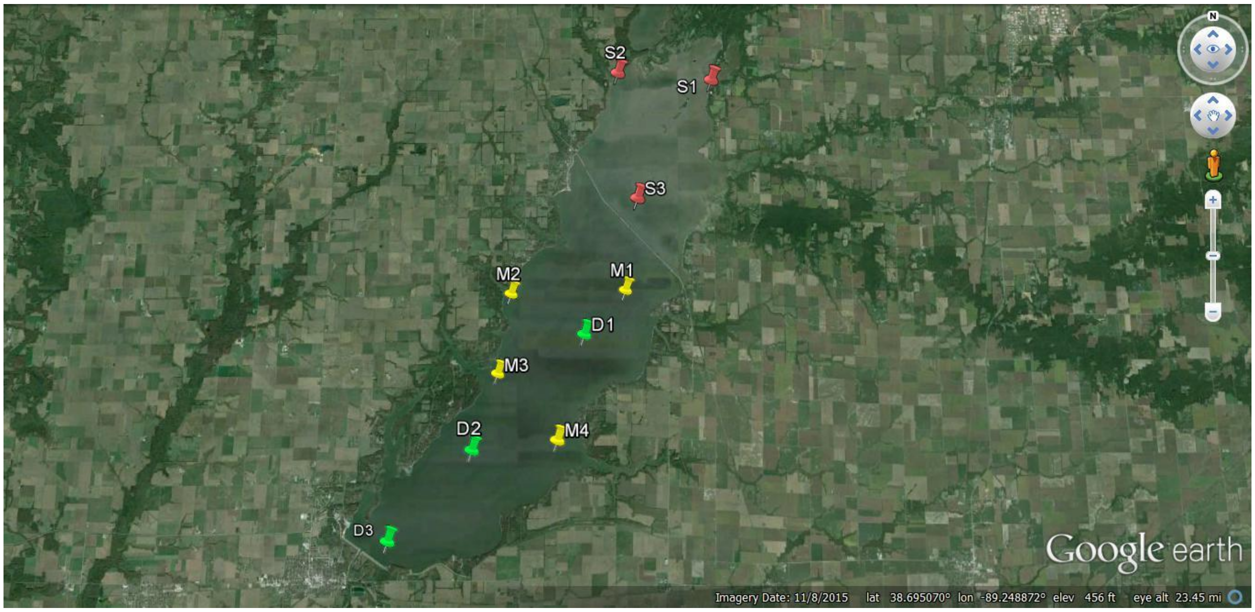


Figure 3. Google Earth view of Carlyle Lake, IL with labels for the 10 sites sampled during five boat excursions. Sampling sites were organized into three deep profiles consisting of shallow (S1, S2, S3), medium (M1, M2, M3, M4), and deep (D1, D2, D3).

Results

Boat-based water sampling: Table 4 shows a condensed summary of the boat-based water quality sampling for NH_4-N, NO_3-N and PO_4-P (i.e., soluble P) for five dates ranging from June 2016 to May 2017. For each date, an average value was calculated for each of the three depth profiles, i.e., shallow, medium, and deep. The shallow depth corresponds to that part of Carlyle Lake that is north of the 4-mile railroad levee (Fig. 3) and which receives incoming water from the Kaskaskia River. Changes in water conditions in the shallow part of the lake (S1, S2, S3) due to inflow from the Kaskaskia River are slow to affect conditions in the lower part of the lake (M1, M2, M3, M4, D1, D2, D3) because interaction can only occur through four narrow openings in the railroad levee totaling 900 ft in width.

Nitrate: In general, NH_3-N and NO_3-N concentrations in Carlyle Lake were lower than concentrations observed in other river systems in Illinois, including the Illinois and Mississippi Rivers. Also noteworthy was the fact that nitrate concentrations tended to be significantly higher in the shallow part of the lake (S1, S2, S3) versus the medium (M1, M2, M3, M4) and deep depths (D1, D2, D3). This is evidence that water that enters Carlyle Lake from the Kaskaskia River contains moderate amounts of nitrate due to tile drainage from intensively managed row crop agriculture. However, denitrification occurs in the shallow part of the lake and by the time water exits Carlyle Lake, the nitrate concentration has been considerably reduced. It is important to remember that Lake Shelbyville, upstream from Carlyle Lake, intercepts much of the nitrate-laden water that drains into the Kaskaskia River from intensively managed agricultural landscapes, and removes a significant amount of the nitrate through denitrification processes. Therefore, water entering Carlyle Lake that originated in Lake Shelbyville has already been exposed to conditions conducive to denitrification. The amount of water from Lake

Shelbyville that reaches Carlyle Lake varies widely throughout the year and also from year to year but is probably less than 20% based on a comparison of the size of the watershed that drains into Lake Shelbyville (675,055 acres) versus Carlyle Lake (3,110,605 acres), as well as Kaskaskia River discharge measured at USGS gages at Shelbyville (05592000) and Vandalia (05592500).

Phosphorus: Soluble P concentrations in filtered samples (<0.45 µm) tended to be more variable than nitrate concentrations, and during the summer of 2016, concentrations reached levels that are considered excessive for general water quality standards. In contrast to nitrate, the soluble P concentrations were frequently higher in the deeper layers of lake water versus mid and surface layers (Table 4), especially during periods with warmer water temperatures (Appendix B). It's unclear why this occurs, but it is possible that during the warm summer months, phosphorus is released from lake sediments and diffuses into the water column. Phosphorus chemistry in sediments is strongly influence by oxidation/reduction processes. Although we could not measure dissolved O_2 concentrations in the sediment layer, it was possible to measure dissolved O_2 at multiple depths throughout the lake. Fig. 4 shows the relationship between dissolved O_2 and depth for the samples that were collected from the deep part of the lake (D1, D2, and D3). Dissolved O_2 clearly decreased with depth and for some sampling dates in June and July, when water temperatures exceeded 25°C, dissolved O_2 concentrations near the sediment layer were below 2 mg/L which suggests anoxic conditions. It is likely that at certain times of the year, conditions in the sediment layer are favorable for the release of phosphorus due to reducing (anoxic) conditions. If this were the case, it might be possible to see elevated concentrations of soluble P in the layer of water immediately above the sediment layer such as those we reported in Table 4. Furthermore, total P concentrations in the sediment layer were correlated to soluble P concentrations in pore water extracted from the sediment layer (Fig. 5A), as well as soluble P concentrations in the layer of water within 2 feet of the sediment layer (Fig. 5B), but showed little correlation to soluble P concentrations at mid and surface depths (Fig. 5C and 5D). These correlations suggested that the sediment layer was a source of soluble P in Carlyle Lake because the impact of the sediment layer was strongest on water in intimate contact with the sediment layer or in close proximity to the sediment layer, but grew weaker with distance from the sediment layer.

Suspended Sediments: Most of the impaired waters in the Kaskaskia River watershed have sedimentation and total suspended solids (TSS) listed as primary causes of impairment. Furthermore, suspended sediments are strongly associated with the transport of total P through the watershed. We measured TSS concentrations concurrently with the nutrient concentrations for the five sampling excursions on Carlyle Lake (Appendix B) and found that TSS values ranged from 8 to 216 mg/L with a median value of 28 mg/L. However, in contrast to dissolved phosphorus, TSS tended to be higher in the Shallow part of Carlyle Lake where wave action had a greater disrupting effect on bottom sediment that in the medium and deep parts of the lake. Sediments that become re-suspended in the water column in the shallow part of the lake (S1, S2, S3) as a result of wave action are eventually transported to the medium (M1, M2, M3, M4) and deep (D1, D2, D3) parts of the lake where they can undergo additional biogeochemical transformations, and possibly contribute to future algal blooms.

Table 4. Average nutrient concentrations in water samples collected from shallow, medium, and deep depth profiles at Carlyle Lake from 6/6/2016 to 5/21/2017. Values were calculated by averaging across sites and depths for each depth profile. The number of values in each average is indicated by the *n* value, which was constant for the medium and deep sites, but varied for the shallow site depending on water levels in the lake when the samples were collected.

Sample Date	**Depth Profile**	***n***	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**PO4-P (mg/L)**
6/6/16	Shallow	5	0.05	1.64	0.04
	Medium	12	0.11	0.87	0.02
	Deep	9	0.05	0.96	0.02
6/23/16	Shallow	6	0.06	3.26	0.10
	Medium	12	0.03	0.20	0.13
	Deep	9	0.09	0.02	0.15
7/28/16	Shallow	6	0.18	2.05	0.12
	Medium	12	0.13	0.71	0.26
	Deep	9	0.14	0.50	0.29
10/28/16	Shallow	6	0.12	0.83	0.15
	Medium	12	0.03	0.25	0.14
	Deep	9	0.01	0.21	0.14
5/21/17	Shallow	9	0.01	1.14	0.12
	Medium	12	0.05	0.95	0.18
	Deep	9	0.09	0.92	0.18

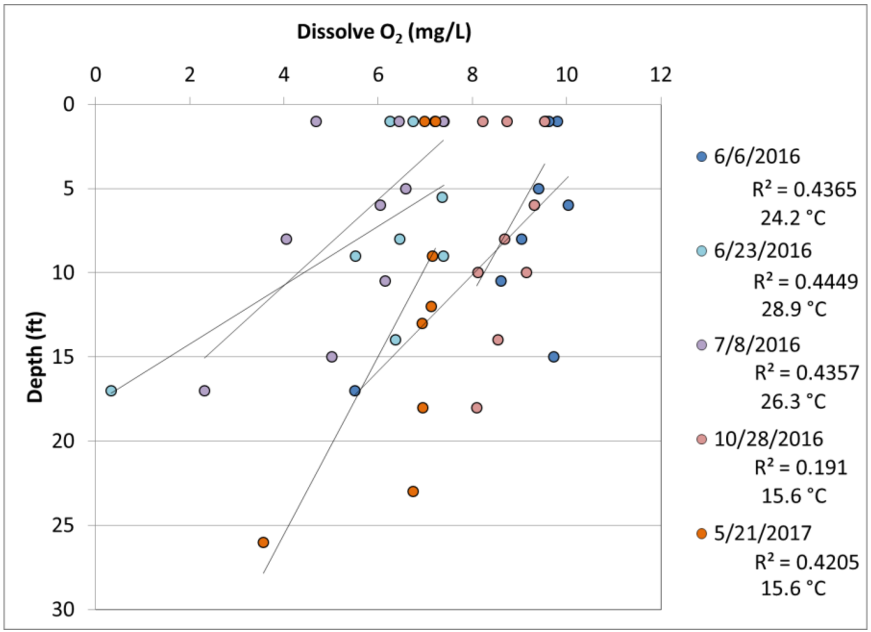
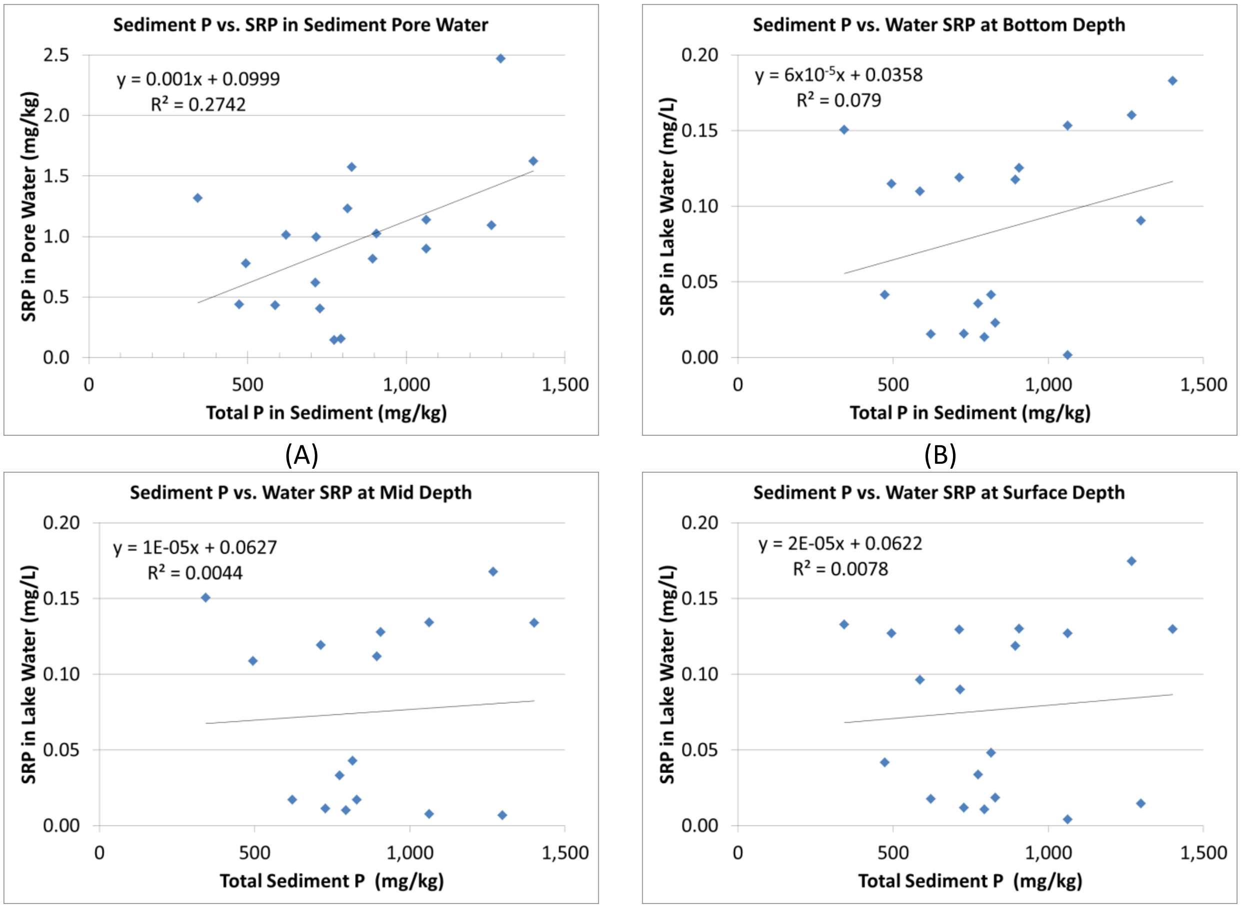


Figure 4. Dissolved O_2 concentrations versus depth in Carlyle Lake for five sampling dates. Linear regression R^2 values are shown for each sampling date as well as the average water temperature.

Figure 5. Comparison between the total P concentration in the 0-5 cm of lake sediment and the soluble reactive phosphorus (SRP) concentration in sediment pore water (A), and water collected from the bottom (B), middle (C), and surface (D) of the lake water column.



(A) (B)

(C) (D)

Cycle-P orthophosphate monitoring: During the summer of 2016, NGRREC maintained a Cycle-P orthophosphate analyzer on Carlyle Lake as a component of the GREON buoy. The Cycle-P measures orthophosphate in a water sample that has been filtered through a 10 µm filter. During the period of time the Cycle-P was actively monitoring water quality, orthophosphate concentrations ranged from <0.01 to 0.37 mg/L (Fig. 6). These concentrations were comparable to the concentrations measured during the boat-based sampling excursions conducted starting in June 2016 and continued through May 2017. A rapid increase in phosphorus concentration began in mid-June after the first boat-based excursion. An examination of Kaskaskia River discharge during the same time period showed that there were multiple spikes in the hydrograph which indicates that there were several flushes of runoff from the Kaskaskia watershed into the Kaskaskia River and eventually Carlyle Lake. The increase in phosphorus concentrations in Carlyle Lake can be attributed to an influx of nutrients and sediments from the watershed. This relationship demonstrates the need to consider the impact of the entire watershed on water quality in the Kaskaskia River and it suggests that reducing runoff from the watershed will prevent nutrients and sediments from entering the river system. Reducing runoff is achieved by increasing infiltration of rainfall into the soil through the adoption of conservation practices on agricultural lands and the adoption of best management storm water practices in urban areas.

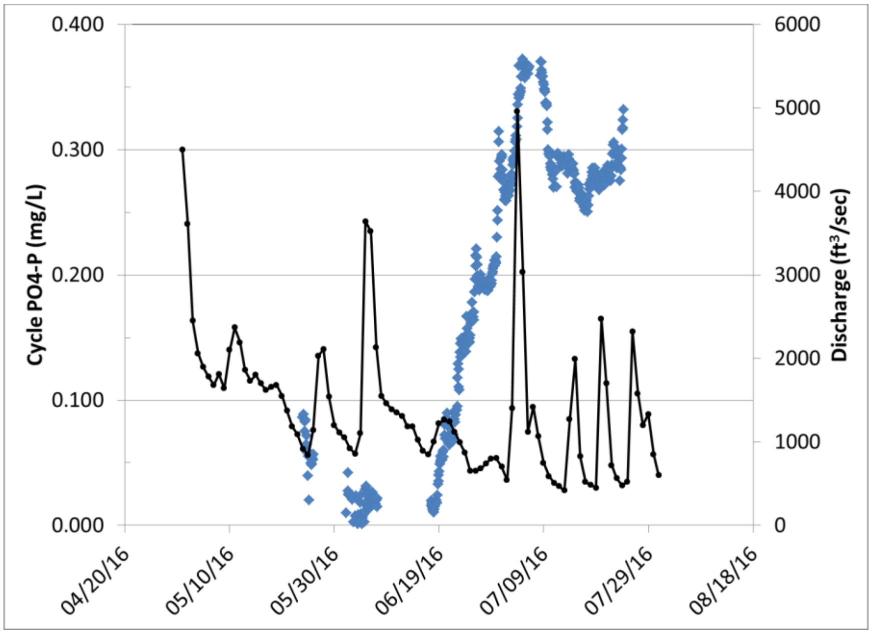


Figure 6. Relationship between soluble phosphorus (<10 µm) in Carlyle Lake measured with a Cycle-P in-situ analyzer (blue diamonds) and Kaskaskia River discharge measured upstream at Vandalia, Illinois at USGS gage 05592500.

SUMMARY

An analysis of land use practices in representative parts of the Kaskaskia River watershed show that although conservation practices are currently be used by many farmers, there is an opportunity to significantly increase the use of practices such as reduced tillage and no-tillage. Water quality monitoring in Carlyle Lake show that nitrogen concentrations are not excessive and some denitrification occurs in the lake. However, phosphorus concentrations are excessive and probably due to the combined effects of runoff from agricultural and urban areas, as well as seasonal release of phosphorus from sediments in Carlyle Lake.

OTHER DIRECTED ACTIVITIES: No briefings have been schedule by IEPA to date.

BUDGET: Heartlands Conservancy is the grant recipient and NGRREC is a sub-awardee. HeartLands Conservancy received the final invoice from NGRREC for work performed through June 30, 2017, and has subsequently submitted said invoice for reimbursement to IEPA in July.

Total budget: $100,000
April 2017 Invoice: $51,080.67
July 2017 Invoice: $48,919.33

APPENDICES:

A. Location of the Kaskaskia River Watershed within the State of Illinois
B. Exo2 sonde water quality data from Carlyle Lake

END REPORT

Appendix A

Location of the Kaskaskia River Watershed within the State of Illinois

Appendix B

Exo2 sonde water quality data from Carlyle Lake for sampling excursions on:
6/6/2016
6/23/2016
7/8/2016
10/28/2016
5/21/2017

Table A1. Measurements of water quality taken on June 6, 2016 in Carlyle Lake, IL using a handheld YSI, Inc. EXO2 multi-parameter sonde. Readings for each parameter were collected continuously for 30 seconds, and the average value for that interval is reported here.

Sample site	Measurement depth (ft)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	fDOM (QSU)	Turbidity (FNU)	Chlorophyll (µg/L)	Blue Green Algae (µg/L)
S1	0.0	27.1	354.4	8.4	22.1	159.6	27.0	2.0
	1.5	24.6	343.2	6.5	16.2	261.0	27.9	1.8
S2								
S3	0.0	29.1	149.3	7.4	15.4	18.9	8.6	1.0
	2.0	24.1	374.9	8.0	41.9	45.3	25.9	1.9
	3.5	24.1	377.0	8.0	42.0	44.6	25.8	1.9
M1	0.0	24.8	331.0	9.9	32.8	16.4	26.7	2.8
	4.0	24.0	360.7	10.2	37.1	19.1	32.8	3.4
	8.0	23.8	361.8	9.5	38.0	20.4	30.4	3.0
M2	0.0	23.5	251.1	8.0	26.1	22.1	10.1	1.4
	4.0	23.6	399.7	6.0	48.5	41.7	19.7	1.7
	7.0	23.5	399.9	5.5	42.8	72.9	21.2	1.8
M3	0.0	24.5	355.6	8.6	35.0	19.3	14.5	1.8
	6.0	24.0	360.0	8.3	36.0	20.8	16.8	1.8
	12.5	23.7	359.8	7.7	34.0	34.6	13.3	1.4
M4	0.0	25.5	284.9	9.1	28.6	12.0	18.6	2.4
	5.5	24.1	359.1	9.7	36.3	19.0	23.2	2.9
	11.0	23.9	353.6	9.1	37.6	23.7	17.5	2.3
D1	0.0	24.2	354.8	9.8	35.1	17.9	20.6	2.6
	5.0	24.0	358.4	9.4	35.6	19.8	21.9	2.6
	10.5	23.8	358.4	8.6	35.1	25.7	18.3	2.0
D2	0.0	23.9	149.2	9.6	19.1	91.1	17.0	3.1
	6.0	23.7	381.9	10.0	51.4	9.1	24.4	3.2
	15.0	23.6	382.6	9.7	51.1	13.1	22.4	2.8
D3	0.0	23.3	388.3	9.6	53.3	6.8	29.2	3.0
	8.0	23.1	390.5	9.1	54.3	7.8	23.9	3.3
	17.0	21.8	404.3	5.5	56.2	15.6	12.5	2.1

Table A2. Measurements of water quality taken on June 23, 2016 in Carlyle Lake, IL using a handheld YSI, Inc. EXO2 multi-parameter sonde. Readings for each parameter were collected continuously for 30 seconds, and the average value for that interval is reported here.

Sample site	Measurement depth (ft)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	fDOM (QSU)	Turbidity (FNU)	Chlorophyll (µg/L)	Blue Green Algae (µg/L)
S1	0.0	31.6	395.4	11.8	24.9	79.0	64.7	5.5
	1.5	31.6	443.3	13.1	28.6	80.8	66.4	5.5
S2	0.0	30.6	473.1	9.3	20.0	75.1	29.5	3.7
S3	0.0	28.6	347.6	7.2	33.2	52.7	34.4	3.7
	2.0	28.6	465.0	7.2	35.4	53.9	31.4	3.1
	3.5	28.6	464.6	7.1	35.3	54.2	33.6	3.0
M1	0.0	29.9	258.3	7.6	24.7	56.4	37.8	4.5
	4.0	28.7	343.5	7.8	38.1	35.5	49.1	5.6
	8.0	28.6	343.9	7.5	37.9	37.5	50.7	5.6
M2	0.0	28.9	361.5	8.8	40.8	31.7	52.8	5.0
	4.0	28.6	374.0	7.0	41.0	37.9	52.2	4.0
	7.0	28.5	379.1	6.2	38.5	50.9	50.8	3.6
M3	0.0	28.5	351.8	7.4	40.0	37.7	51.0	5.3
	6.0	28.5	350.4	7.1	39.8	39.0	47.9	4.4
	12.5	28.3	347.2	6.7	39.0	43.5	45.9	4.3
M4	0.0	29.9	222.9	7.7	24.6	17.5	18.2	3.3
	5.5	28.4	350.2	7.4	39.0	25.9	27.1	4.2
	11.0	28.2	351.4	6.8	38.2	32.2	25.3	3.9
D1	0.0	29.3	122.2	7.4	15.0	179.0	20.7	3.8
	5.0	28.8	346.7	7.4	37.5	29.8	34.8	5.4
	10.5	28.8	346.8	7.4	37.3	30.5	34.2	5.4
D2	0.0	28.2	323.5	6.7	38.1	21.9	25.1	4.1
	6.0	28.1	351.4	6.5	41.4	23.9	26.8	3.9
	15.0	28.1	351.5	6.4	41.3	25.5	27.2	3.8
D3	0.0	28.3	351.0	6.3	37.3	30.0	25.9	4.6
	8.0	28.2	352.3	5.5	38.1	31.6	25.3	3.8
	17.0	27.1	363.4	0.3	42.1	30.7	14.4	2.2

Table A3. Measurements of water quality taken on July 8, 2016 in Carlyle Lake, IL using a handheld YSI, Inc. EXO2 multi-parameter sonde. Readings for each parameter were collected continuously for 30 seconds, and the average value for that interval is reported here.

Sample site	Measurement depth (ft)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	fDOM (QSU)	Turbidity (FNU)	Chlorophyll (µg/L)	Blue Green Algae (µg/L)
S1	0.0	30.8	11.6	7.3	-4.2	0.6	1.9	2.1
	1.5	30.0	269.8	8.2	46.6	78.1	16.7	2.3
S2	0.0	27.8	302.0	6.7	52.8	63.9	10.9	1.6
S3	0.0	27.0	70.4	7.6	11.4	4.9	3.0	2.2
	2.0	25.5	291.8	6.3	48.7	52.4	11.0	2.1
	3.5	25.5	292.8	6.3	48.8	52.4	11.1	2.0
M1	0.0	26.9	101.5	7.8	14.9	2.8	1.4	1.0
	4.0	26.2	354.7	7.1	47.8	24.4	8.3	4.0
	8.0	26.2	356.0	6.7	47.0	28.2	8.6	3.9
M2	0.0	27.5	190.1	7.6	27.9	10.8	6.3	1.9
	4.0	26.6	338.8	7.1	48.8	29.2	10.2	3.3
	7.0	25.6	341.5	5.5	46.0	41.7	11.5	2.9
M3	0.0	28.1	130.2	7.5	18.2	3.3	3.4	2.5
	6.0	25.6	365.1	6.8	50.2	17.5	8.1	3.0
	12.5	25.2	371.2	6.0	50.2	19.6	6.7	2.8
M4	0.0	25.5	356.9	5.6	50.1	21.9	5.5	2.1
	5.5	25.4	356.8	5.4	50.0	23.0	6.1	2.1
	11.0	25.4	356.5	5.2	48.5	29.2	6.1	2.1
D1	0.0	25.8	336.0	7.4	49.5	11.3	4.7	1.9
	5.0	25.7	360.0	6.6	49.4	22.9	6.9	3.1
	10.5	25.6	360.0	6.2	48.4	27.0	6.8	2.9
D2	0.0	25.2	374.5	6.5	50.2	17.9	6.7	2.8
	6.0	25.1	375.7	6.0	50.4	19.8	7.6	2.9
	15.0	25.0	374.6	5.0	46.7	33.0	7.0	2.8
D3	0.0	25.0	361.9	4.7	53.8	16.4	4.7	1.9
	8.0	24.9	363.3	4.1	53.1	20.6	4.8	1.8
	17.0	24.6	363.4	2.3	53.8	23.2	4.6	1.6

Table A4. Measurements of water quality taken on October 28, 2016 in Carlyle Lake, IL using a handheld YSI, Inc. EXO2 multi-parameter sonde. Readings for each parameter were collected continuously for 30 seconds, and the average value for that interval is reported here.

Sample site	Measurement depth (ft)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	fDOM (QSU)	Turbidity (FNU)	Chlorophyll (µg/L)	Blue Green Algae (µg/L)
S1	0.0	16.8	304.6	7.5	53.8	92.1	8.6	1.1
	1.5	15.2	372.1	6.4	57.6	95.7	8.8	1.0
S2	0.0	16.4	361.5	7.2	56.9	99.7	11.7	1.3
S3	0.0	14.4	302.1	8.0	84.5	36.7	15.7	1.5
	1.5	14.4	302.3	7.8	84.5	36.7	17.3	1.5
	3.0	14.3	303.4	7.8	82.3	39.3	19.2	1.5
M1	0.0	15.3	253.8	8.7	58.9	24.2	14.3	2.0
	5.0	15.2	300.6	8.6	62.8	24.6	21.0	2.2
	8.0	15.1	300.3	8.4	63.7	25.4	22.6	2.2
M2	0.0	15.6	293.0	9.6	51.0	20.3	14.3	2.3
	4.5	15.6	295.1	9.0	50.5	22.5	16.1	2.2
	7.0	15.6	295.2	8.9	50.2	22.7	16.8	2.1
M3	0.0	16.0	281.6	8.9	49.8	20.8	15.4	2.3
	7.0	16.0	297.0	8.7	50.0	21.4	14.9	2.1
	12.0	16.0	297.0	8.7	50.0	21.0	16.3	2.1
M4	0.0	15.8	261.4	9.7	51.9	18.5	14.4	2.2
	6.0	15.6	300.5	9.3	52.7	20.1	20.8	2.4
	10.0	15.5	300.8	9.0	52.0	22.3	23.8	2.5
D1	0.0	15.5	296.7	9.5	53.8	18.0	19.2	2.5
	6.0	15.4	306.2	9.3	55.1	18.7	24.8	2.6
	10.0	15.3	306.2	9.2	56.2	19.3	27.2	2.6
D2	0.0	16.0	297.9	8.7	50.9	20.7	16.3	2.3
	8.0	16.0	297.9	8.7	50.7	20.3	15.9	2.1
	14.0	16.0	298.2	8.5	49.0	26.8	16.9	2.2
D3	0.0	16.1	294.5	8.2	50.1	17.7	13.5	1.9
	10.0	16.1	295.0	8.1	50.2	18.0	13.8	1.9
	18.0	16.1	295.1	8.1	50.1	18.3	14.1	1.9

Table A4. Measurements of water quality taken on May 21, 2017 in Carlyle Lake, IL using a handheld YSI, Inc. EXO2 multi-parameter sonde. Readings for each parameter were collected continuously for 30 seconds, and the average value for that interval is reported here.

Sample site	Sample Depth (ft)	Temp (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	fDOM (QSU)	Turbidity (FNU)	Chlorophyll (µg/L)	Blue-Green Algae (µg/L)
S1	1	22.9	332.7	8.45	63.55	19.8	26.9	2.13
S1	4	22.9	337.3	8.38	63.23	19.9	32.7	2.39
S1	8	22.8	342.4	8.29	62.84	20.4	34.4	2.47
S2	1	24.3	234.3	10.1	71.13	15.7	30.6	2.40
S2	4	22.8	255.5	7.33	70.83	20.8	26.3	1.69
S2	8	22.0	258.4	5.79	69.48	32.1	15.8	0.80
S3	1	21.9	207.6	7.6	71.06	31.7	8.42	0.70
S3	5	21.9	207.7	7.51	70.51	32.6	9.11	0.65
S3	11	21.8	207.2	7.43	70.14	34.2	8.73	0.61
M1	1	21.7	223.0	7.09	67.98	43.0	3.76	0.24
M1	8	21.7	223.0	7.03	67.95	43.8	3.96	0.25
M1	16	21.6	223.2	6.97	68.06	44.0	4.03	0.26
M2	1	21.4	214.5	6.85	68.93	42.0	3.62	0.26
M2	7	21.4	214.7	6.84	69.15	41.8	3.88	0.23
M2	15	21.3	214.6	6.73	69.14	42.0	3.81	0.22
M3	1	21.2	216.3	7.11	68.79	44.8	3.62	0.25
M3	10	21.2	216.3	7.02	68.67	44.2	3.80	0.25
M3	20	20.9	220.7	6.07	61.05	76.9	4.97	0.37
M4	1	20.9	223.4	7.35	70.67	38.2	3.72	0.25
M4	9	20.7	223.6	7.19	72.1	38.4	4.07	0.25
M4	18	20.6	223.7	7.13	72.19	39.2	3.99	0.25
D1	1	21.3	220.4	7.2	69.41	42.4	3.56	0.23
D1	9	21.3	220.5	7.15	69.29	42.1	3.66	0.23
D1	18	21.1	221.5	6.95	69.63	41.9	3.69	0.23
D2	1	20.5	222	7.22	71.49	40.3	3.89	0.25
D2	12	20.5	222.1	7.13	71.63	39.8	4.18	0.25
D2	23	20.3	224.3	6.74	71.75	40.4	3.99	0.23
D3	1	20.2	225.7	6.99	72.59	38.8	4.09	0.23
D3	13	20.2	225.8	6.93	72.82	38.2	4.20	0.24
D3	26	18.9	238.2	3.56	67.63	59.6	4.86	0.38