An Estimation of the Annual Loading of Total Phosphorus and Sediment into Hillsdale Lake, 2001

By: Jason Downs, Field Representative
Hillsdale Water Quality Project, Inc.
June 27, 2002

Introduction

Hillsdale Lake and its watershed lie in the Lower Marais des Cygnes Basin in eastern Kansas. The Hillsdale Watershed is 144 square miles and spans four counties. The lake is used primarily for flood protection, fish and wildlife, recreation and as a public water supply. More than 30,000 residents in Johnson and Miami County are supplied drinking water from the lake. The use of Hillsdale Lake as a public water supply is expected to proportionately increase with the areas rapid growth and urbanization. About 6.6 million gallons of water per day is currently allocated for public consumption and about 8.2 million gallons per day remains available.

In recent years, there has arisen a concern that the water quality in Hillsdale Lake and its tributaries has diminished. Currently, the Kansas Department of Health and Environment lists Hillsdale Lake as eutrophication impaired. Therefore, a eutrophication TMDL (Total Maximum Daily Load) has been implemented for Hillsdale Lake. Phosphorus and sediment are contributing factors to eutrophication. The geology and soil characteristics in the area naturally allow large quantities of sediment and nutrients into local streams the lake. However, agriculture, urban development and other land uses have exacerbated this phenomenon. Phosphorous and sediment levels have particularly become a source of concern. Phosphorus in Hillsdale Lake's Watershed is limiting concerning algal and plant requirements, meaning it is the nutrient that limits biological growth. An excessive amount of phosphorus in the water column can lead to high aquatic production of biomass. This can affect the clarity, taste and odor of the water and inflicts stress on aquatic organisms. Excessive sediment deposition can dramatically decrease the design life of the reservoir by taking up floodwater storage space. Sediment can also bury fish spawning areas and benthic organisms in lakes and streams. Harmful chemicals can also attach to sediment and become deposited with it affecting water quality.

The Hillsdale Water Quality Project resolved to improve the quality of water entering Hillsdale Lake. In early 1998 specific water quality goals were established that included a reduction of the annual phosphorus load to the lake by 30% or 21,000 kg/year (based on USGS Sediment Study Estimate of 70,000 kg/year entering the lake from 1981 - 1996) and a reduction of the annual sediment load by 30% or 39,750 tons/year (based on USGS Sediment Study Estimate of 132,500 tons/year entering the lake from 1981 - 1996).

The purpose of this study is to monitor the status of phosphorus and sediment loading into Hillsdale Lake by estimating the input of total phosphorus and sediment in 2001. This may identify a general trend in phosphorus and sediment loading as monitoring continues. The estimations were derived using total phosphorus and total suspended solids concentration data from the lake's major tributaries. This data was obtained through the analysis of samples taken by HWQP using established methods at these sites. A map detailing the sampling locations within the watershed and the 2001-sampling plan are provided in the supplemental information section (p. 16). A general trend in total phosphorus and sediment loading will allow progress made by the project's efforts to be assessed. The project and its volunteers should not expect to see significant trends in total phosphorus and sediment reduction in a short period of time, as noted by Ed Carney with the Kansas Department of Health and Environment. However, the Hillsdale Water Quality Project believes if this process continues to be carried out in future years it can be assumed that trends will continue. It may also place the size of the problems that need to be faced into greater perspective.

Methods of Estimation

Prior to 1999, loading estimates were calculated using a method that was developed by Michael D. Franano with the help of board members and technical advisers. It was used in his study, Hillsdale Lake Water Quality Assessment and Phosphorus Load Estimate. This method involved calculating the average yearly concentration in the monitored streams – Big Bull Creek, Little Bull Creek, Rock Creek and Wade Creek – and multiplying these concentrations by the total annual water flow into Hillsdale Lake. This initial calculation method was ideal to obtain rough estimations with minimal resources, but there was understandably likelihood for error.

The only stream flows in the watershed currently monitored by the U.S. Geological Survey gauging stations are at the Big Bull and Little Bull sampling sites. Using Franano's method, the annual flow for these streams was multiplied by the average total phosphorus concentration of grab samples and storm runoff samples at these sites to obtain the estimated annual load from these two tributaries. When these calculations were completed, the annual flow from these two sites was subtracted from the lake's total annual inflow (estimated by USACE) and the remaining flow was used in the "other" calculation. The concentration for all other tributaries in the watershed was determined by averaging the yearly average concentrations from all sampled tributaries. This average concentration was then multiplied by the remaining flow to estimate the load from the watershed's unmonitored tributaries. The "other" total was then added to the Big Bull and Little Bull loading estimates to derive a total loading estimate.

Members of the Hillsdale Water Quality Project staff refined this method in 2000, largely based on Anthony A. Holt's study, Estimation of 1994 Point Source And Non-point Source Phosphorus Loading to Hillsdale Lake, for calculating yearly total phosphorus loading. The board approved this plan on March 16, 2000. This refined method provides estimates that should be more accurate and will be used until otherwise noted.

First, direct precipitation is determined using rainfall data obtained from the National Weather Service (collected by the U.S. Army Corps of Engineers) and the total phosphorous concentration in rainfall suggested by Dr. John R. Jones in his 1998 study, Evaluation of the Limnology of Hillsdale Lake, Kansas. Next, composite sampling data collected from the Big Bull and Little Bull creeks is used to estimate the amount of total phosphorous and sediment that flows into the lake during storms from these two streams. Then, a low-flow estimate is made for these two tributaries using an average of the mean daily flows for the sampling year and the average concentrations of total phosphorous and sediment found in the grab samples. The next step finds an estimate of the total phosphorus and sediment loads for all events that do not fall under low flow or storm flow. Finally, an estimate of the total phosphorous and sediment load from all other tributaries in the watershed is made. The combined totals of the preceding steps are used to calculate the estimated total phosphorus and sediment load input to Hillsdale Lake.

Loading from Direct Precipitation – Phosphorus Loading Only

The contribution of phosphorus from direct precipitation is found by multiplying the volume of direct precipitation (liters) into the lake by 0.05 mg/L (Jones) and dividing the result by 1,000,000 to obtain the mass of phosphorus in kilograms (there are 1,000,000 milligrams in 1 kilogram). During the year 2001, 37.49 inches of precipitation fell on Hillsdale Lake (National Weather Service) or 17,627,924,920 liters. Using the multiplication described above,

$$\frac{(0.05 \text{ mg/L}) \text{ X } (17{,}627{,}924{,}920 \text{ L})}{1{,}000{,}000 \text{ mg/Kg}}$$

It is found that **881 Kg** of the phosphorus input to Hillsdale Lake came from precipitation.

Loading from Storm Runoff

The total phosphorus and sediment loading resulting from storm flow in Big Bull Creek and Little Bull Creek is found by multiplying the concentrations of the nutrients from each composite sample collected by the volume of water passing the sample site during that time.

Flow data in cubic feet per second, taken every 15 minutes, is multiplied by 60 seconds and then by 15 minutes to obtain the storm flow volume in cubic feet for that particular 15-minute period. These flow volumes are each multiplied by the total phosphorous or sediment concentration of the event and then by 28.32 Liters per cubic foot. The 28.32 multiplier is used to remove the liters and cubic feet from the equation so as to be left with milligrams of total phosphorus. This total is then divided by 1,000,000 to yield the amount of phosphorous in kilograms passing the site for that 15-minute period. The calculation is shown below:

$$\frac{(\text{flow in cubic feet } [ft^3])(28.32 \text{ L}/ft^3)(\text{nutrient concentration in mg/L})}{1{,}000{,}000 \text{ mg/Kg}}$$

The amounts for each 15-minute period were then summed to obtain the amount of phosphorus loading during the entire event. This loading data from each event was summed, yielding the total amount of phosphorous input into the lake from that specific tributary during high-flow periods.

Using the preceding formula, total phosphorus loading from storm events in Big Bull and Little Bull Creeks in 2001 were:

Big Bull Creek: 7,248 Kg
Little Bull Creek: 2,328 Kg

Using the preceding formula, total sediment loading from storm events in Big Bull and Little Bull creeks in 2001 were:

Big Bull Creek: 4,927,832 Kg
Little Bull Creek: 3,434,421 Kg

Loading from Low-Flow Periods

The equation used to calculate the yearly low-flow contribution of phosphorus from Big Bull Creek and Little Bull Creek is similar to the equation used in the storm runoff calculation, except that the flow was calculated for an entire year instead of a 15-minute interval. The average low-flow was calculated by averaging the mean daily flows, less than 15 ft^3/s in Big Bull and 12 ft^3/s for Little Bull. The average low-flow concentration for each year was obtained by averaging grab samples of that year taken at times when Big Bull flows were less than 15 ft^3/s, and when Little Bull and Rock were less than 12 ft^3/s. Grab samples taken when the creeks exceeded these limits were not used. The equation is as follows:

$$\frac{(\text{flow in cubic feet }[ft^3])(28.32\ L/ft^3)(\text{nutrient concentration in mg/L})}{1{,}000{,}000\ mg/Kg}$$

The total low-flow phosphorus load contributed by Big Bull and Little Bull Creeks in 2001 was:

Big Bull Creek: **4,331 Kg**
Little Bull Creek: **539 Kg**

The total low-flow sediment load contributed by Big Bull and Little Bull Creeks in 2001 was:

Big Bull Creek: **132,786 Kg**
Little Bull Creek: **74,592 Kg**

Loading from Low-Storm Flow Events

Loading from low-storm flow events includes all flow resulting from a rain event that does not exceed daily flow values of 50 ft^3/s at Little Bull Creek, and 100 ft^3/s at Big Bull Creek, does not fall below 13 ft^3/s and 15 ft^3/s respectively, and does not trigger a sampling event. The daily flow for these events is totaled for the entire year. An average concentration is figured from composite samples collected during small storm events, and from grab samples collected during low flow and multiplied by the total flow. This result is then multiplied by 28.32 L/ft^3 and then divided by 1,000,000 mg/Kg to get the answer in kilograms.

$$\frac{(\text{flow in cubic feet [ft}^3])(28.32\ \text{L/ft}^3)(\text{avg. nutrient concentration in mg/L})}{1{,}000{,}000\ \text{mg/Kg}}$$

The total low-storm flow phosphorus load contributed by Big Bull and Little Bull Creeks in 2001 was:

Big Bull Creek: **2,410 Kg**
Little Bull Creek: **1,691 Kg**

The total low-storm flow sediment load contributed by Big Bull and Little Bull Creeks in 2001 was:

Big Bull Creek: **497,814 Kg**
Little Bull Creek: **3,005,835 Kg**

Loading from Other Tributaries

The most difficult part of the load to determine is the contribution from portions of the watershed not including the Big Bull and Little Bull Subwatersheds. Estimating loading from Rock Creek and Wade Creek is also difficult because of the lack of gauging equipment at these sites to calculate flow. The Big Bull Creek and Little Bull Creek sites are the only sites with flow measuring equipment and automatic samplers designed to sample storm runoff. During the 2001 sampling year, about 50 percent of the flow from Big Bull Creek and Little Bull Creek moved past the gauging stations while the automatic samplers were collecting samples. It is estimated that another 17 percent of the flow was at a height that would be considered high-flow but samples were not collected (low-storm flow). Therefore, 33 percent can be used as an amount of total flow from Big Bull Creek and Little Bull Creek that could be considered low-flow and represented by grab sample results. Samples may not have been collected due to operator error, mechanical error, staff decision or the beginning or end of an event being below the sampler activation level. The additional 17 percent representative of low-storm flows was derived from visual estimation from the yearly stream flow hydrographs.

Storm Flow Contribution:
To calculate the contribution of stormwater runoff from the unmonitored portion of the watershed, the amount of water contributed to the lake by direct precipitation and the amount of inflow from Big Bull Creek and Little Bull Creek is subtracted from the total inflow to the lake. The result is the remaining inflow from the rest of the Hillsdale Lake Watershed. Then, an average of all composite sample concentrations collected at the Big Bull Creek and Little Bull Creek sites during the year and 50 percent of the remaining inflow to the lake, are multiplied.

Unmonitored Total Storm Flow =
(0.5) X [(Total Lake inflow) – (Big Bull inflow + Little Bull inflow) – (Direct Precip. volume*)]

Unmonitored Storm Flow Nutrient Load =
(Unmonitored Total Storm Flow) X (Average Storm Flow Concentration)

In 2001, the unmonitored storm flow phosphorus load was **20,213 Kg**.

In 2001, the unmonitored storm flow sediment load was **33,413,602 Kg**.

Low-Storm Flow Contribution:
To calculate the contribution of low-stormwater runoff from all other parts of the watershed, nutrient concentrations of all composite samples collected during low-storm flow events and grab samples (including Big Bull, Little Bull, Rock and Wade Creek sites) collected during low flow are averaged, and multiplied by 17 percent of the remaining inflow to the lake.

Unmonitored Total Low-Storm Flow =
(0.17) X [(total lake inflow) – (Big Bull inflow + Little Bull inflow) – (direct precip. volume)]

Unmonitored Low-Storm Flow Nutrient Load =
(unmonitored total low-storm flow) X (average low-storm flow & low flow concentration)

In 2001, the unmonitored low-storm flow phosphorus load was **5,464 Kg**.

In 2001, the unmonitored low-storm flow sediment load was **7,153,462 Kg**.

Low Flow Contribution:
The remaining 33 percent of flow from the unmonitored part of the watershed are attributed to low-flow conditions and events too small to be monitored.

Unmonitored Total Low Flow =
(0.33) X [(total lake inflow) – (big bull inflow + little bull inflow) – (direct precip. volume)]

Unmonitored Low Flow Phosphorus Load =
(unmonitored total low flow) X (average low flow concentration)

Therefore, an average of grab samples collected from Big Bull, Little Bull, Rock, and Wade creeks is calculated and multiplied by the remaining flow.

In 2001, the unmonitored low flow phosphorus load was **8,984 Kg**.

In 2001, the unmonitored low flow sediment load was **695,241 Kg**.

The <u>total</u> unmonitored phosphorus load was **34,661 Kg**.

The <u>total</u> unmonitored sediment load was **41,262,305 Kg.**

Summary

Now the estimates for each of the following can be summed to obtain total phosphorous and sediment loads for 2001.

Total phosphorus load due to direct precipitation	881 Kg
Total phosphorus load from storm events in Big Bull Creek	7,248 Kg
Total phosphorus load from storm events in Little Bull Creek	2,328 Kg
Total phosphorus load from low-storm flow events in Big Bull Creek	2,410 Kg
Total phosphorus load from low-storm flow events in Little Bull Creek	1,691 Kg
Total phosphorus load during low-flow in Big Bull Creek	4,331 Kg
Total phosphorus load during low-flow in Little Bull Creek	539 Kg
Total phosphorus load from unmonitored storm flow	20,213 Kg
Total phosphorus load from unmonitored low-storm flow	5,464 Kg
Total phosphorus load from unmonitored low flow	8,984 Kg
Total phosphorus load for Hillsdale Lake - 2001 =	**54,089 Kg**

Total sediment load due to direct precipitation	0 Kg
Total sediment load from storm events in Big Bull Creek	4,927,832 Kg
Total sediment load from storm events in Little Bull Creek	3,434,421 Kg
Total sediment load from low-storm flow events in Big Bull Creek	497,814 Kg
Total sediment load from low-storm flow events in Little Bull Creek	3,005,835 Kg
Total sediment load during low-flow in Big Bull Creek	132,786 Kg
Total sediment load during low-flow in Little Bull Creek	74,592 Kg
Total sediment load from unmonitored storm flow	33,413,602 Kg
Total sediment load from unmonitored low-storm flow	7,153,462 Kg
Total sediment load from unmonitored low flow	695,241 Kg
Total sediment load for Hillsdale Lake - 2001 =	**53,335,585 Kg**

Conclusion

Phosphorus Load - 2001

The estimated phosphorus load for 2001 equaled 54,089 Kg. The sediment load totaled 58,792 tons. These were the second lowest amounts since the inception of the project (**fig. 1**). The major factor of the low 2001 phosphorus load was overall low lake inflow although an increase of best management practices within the watershed since the early 1990s may have played a roll. However, phosphorus and sediment loading show a strong correlation with the amount of inflow that occurs (**fig. 2**). In 2001, the lake inflow was 58,261 acre-ft, which was also the second lowest amount recorded. The yearly lake inflow is a direct result of precipitation, and the precipitation total for 2001 was slightly below average. The consistency at which precipitation occurs as well as the yearly precipitation total can also have an effect on phosphorus loading.

Year	Yearly Lake Inflow (acre-ft)	Estimated Phosphorus Load (Kg)	Estimated Sediment Load (Short Tons)
1994	90,733	63,290	99,422
1995	112,747	71,413	127,352
1996	75,922	57,771	132,960
1997	110,870	80,444	107,974
1998	133,521	80,073	155,733
1999	96,357	73,310	98,731
2000	31,690	25,966	19,295
2001	58,261	54,089	58,792

fig. 1. Inflow data provided by the U.S. Army Corps of Engineers.

Data acquired from the National Weather Service indicated total precipitation in 2001 of 37.49 inches. This is a little short of the average yearly total precipitation amount of 42.31 inches (based on U.S. Army Corps of Engineers data 1982 – 1999). The low precipitation amount resulted in a low direct precipitation volume generating less inflow from the tributaries of Hillsdale Lake. In turn, less phosphorus loading occurred in Hillsdale Lake. Obvious conclusions can be made by reviewing **figures 1 and 2** that phosphorus and sediment loading is directly affected by lake inflow.

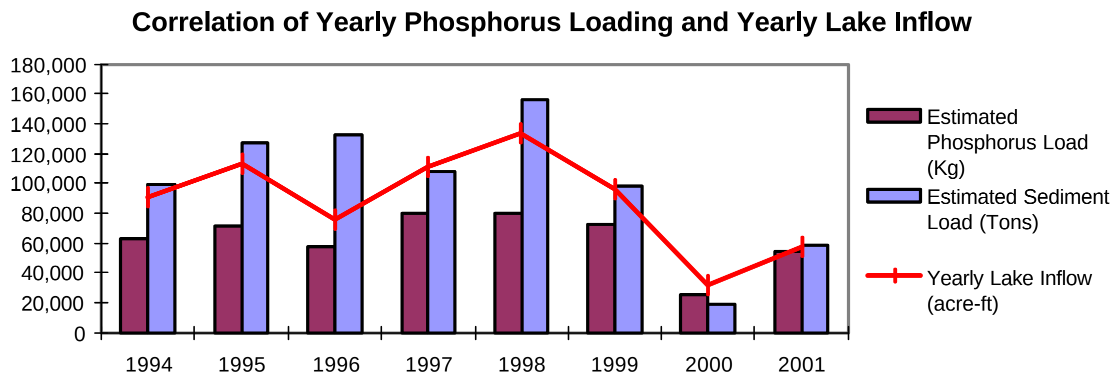


fig. 2. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

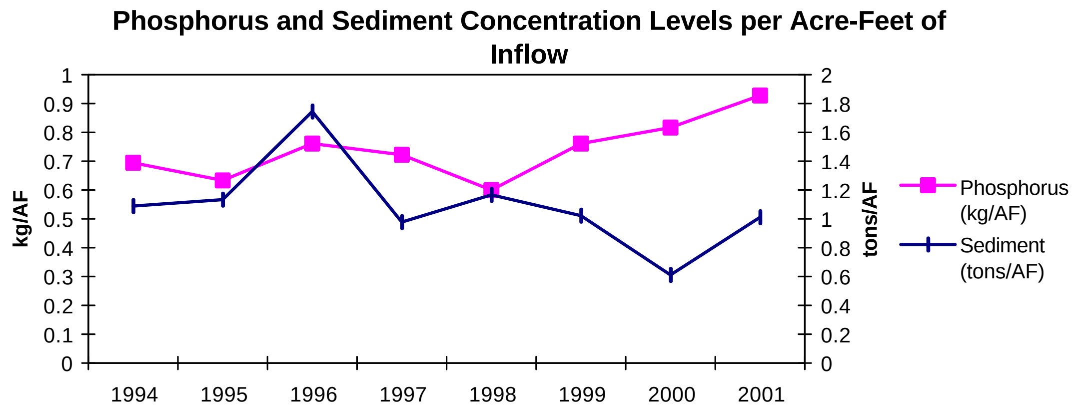


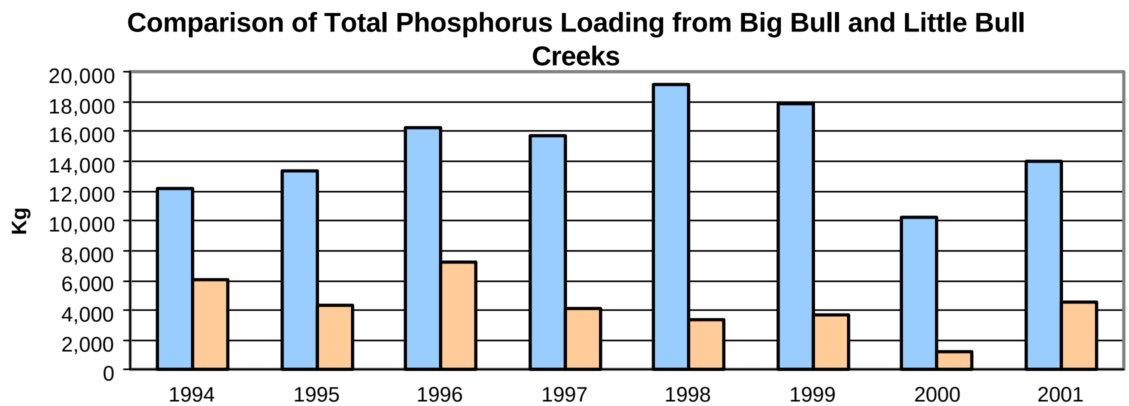
fig. 3. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

It can be determined that phosphorus concentration levels are not directly affected by inflow amount (**fig. 3**). The year 2001 demonstrated a phosphorus concentration higher than previous years. It is likely that this was due to the sporadic precipitation events or "gully washers" that were experienced in 2001. Stream waters were more highly concentrated in phosphorus than events in an average year because more phosphorus could be absorbed into bottom sediments and assimilated into plant materials before being flushed into the lake. This process is known as phosphorus banking (Holt). It can be demonstrated that phosphorus concentrations deplete towards the tail end of a series of closely spaced runoff events because phosphorus banking is not being allowed to occur.

Priority Subwatershed

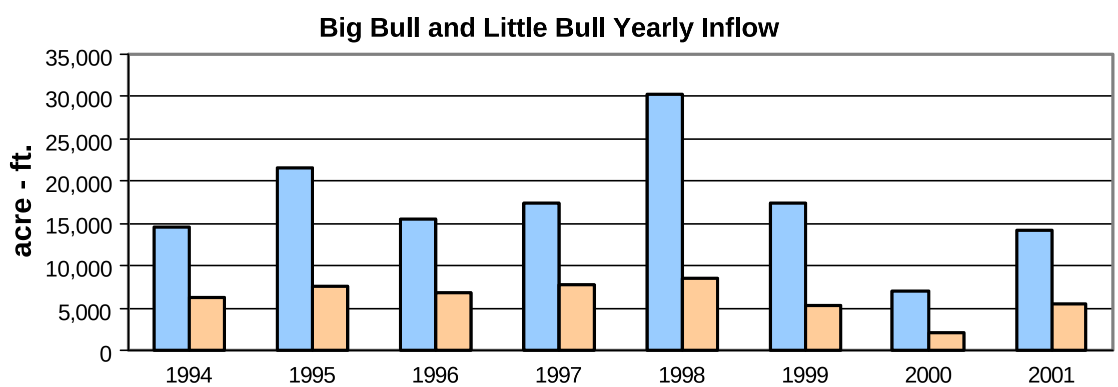
Each year, the Hillsdale Water Quality Project determines a subwatershed that requires the project's special attention. Efforts are made to contact landowners within the area to help spread the implementation of Best Management Practices within the subwatershed. In the past, two subwatersheds were isolated as the largest point and non-point source pollution contributors to Hillsdale Lake. They are the Big Bull and Little Bull subwatersheds. These two subwatersheds have flow gauging equipment and therefore, produce more accurate loading results.

Of these two subwatersheds, Big Bull has consistently had the highest phosphorus load (**fig. 4**). In 2001, Big Bull Creek contributed about three times the total phosphorus load of Little Bull Creek. The main reason for this is the large difference of inflow into Hillsdale Lake (**fig. 5**).



	1994	1995	1996	1997	1998	1999	2000	2001
Big Bull	12,149	13,358	16,211	15,749	19,125	17,843	10,266	13,989
Little Bull	6057	4291	7237	4166	3394	3657	1205	4558

fig. 4. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.



	1994	1995	1996	1997	1998	1999	2000	2001
Big Bull	14,559	21,540	15,457	17,409	30,266	17,475	6,991	14,275
Little Bull	6,319	7,515	6,764	7,785	8,626	5,313	2,061	5,480

fig. 5. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

In an effort to compare the two subwatersheds equally, the phosphorus load per acre-foot of water was analyzed. The results are now independent of the total amount of water that flows through each subwatershed (**fig. 6**). In 2001, Big Bull Creek produced only a 0.10 Kg / AF higher concentration than Little Bull Creek. This is the lowest variance of phosphorus concentration since 1996.

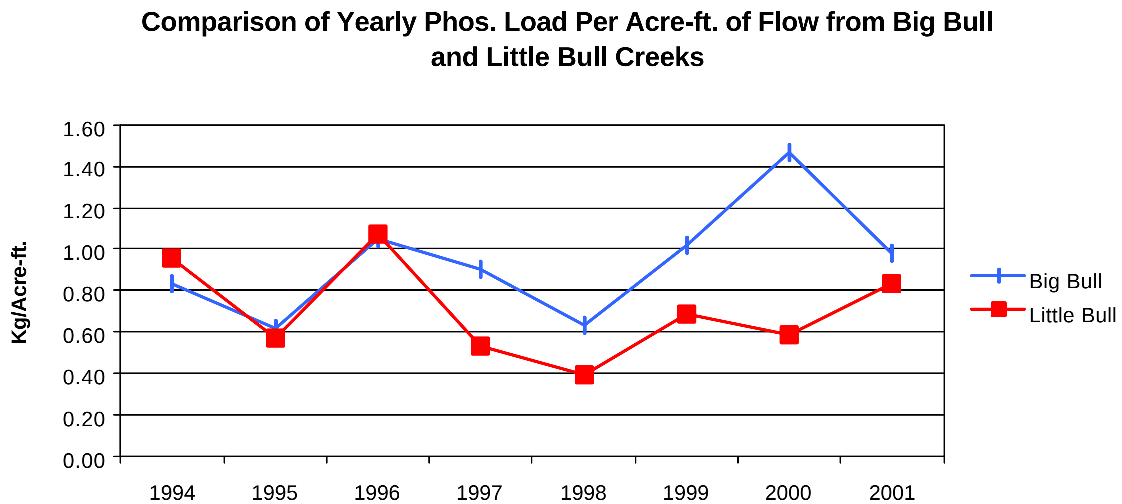


fig. 6. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Similarly, the phosphorus load per acre of land within each subwatershed was analyzed. The Big Bull Subwatershed is 25 percent larger than the Little Bull Subwatershed (Big Bull Subwatershed = 23,628 acres, Little Bull Subwatershed = 17,770 acres). Dividing the acreage of each subwatershed by the amount of phosphorus load contributed by each subwatershed results in the amount of phosphorus that is washed from the surface per acre of each subwatershed. This results in data that is independent of inflow. Big Bull Subwatershed contributed about two times the phosphorus load per acre than the Little Bull Subwatershed (**fig. 7**).

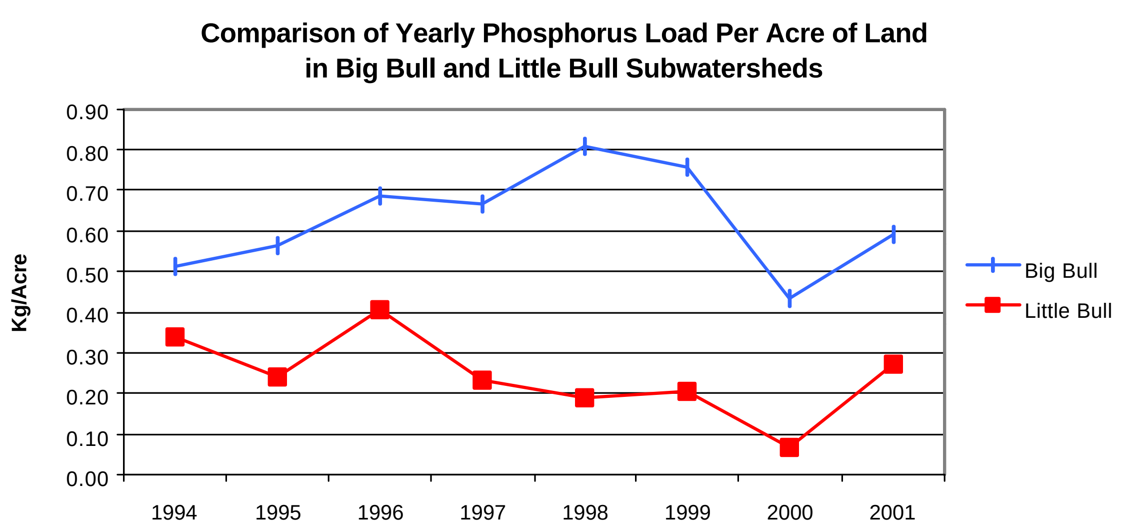


fig. 7. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

The Big Bull Subwatershed has more than 36 percent of all cropland in the Hillsdale watershed. It is also apparent that the subwatershed contributes the greatest load of phosphorus (**fig. 8**). However, high sediment concentrations (nearly 5200 mg/L) were found in Little Bull Creek in 2001 during storm and low-storm runoff events. Sediment concentrations found in Little Bull Creek exceeded those in Big Bull Creek in all but one runoff event. The sediment load from Little Bull Creek surpassed loading from Big Bull Creek by over 1 thousand tons or about 2 percent of the total sediment load (**fig. 9**).

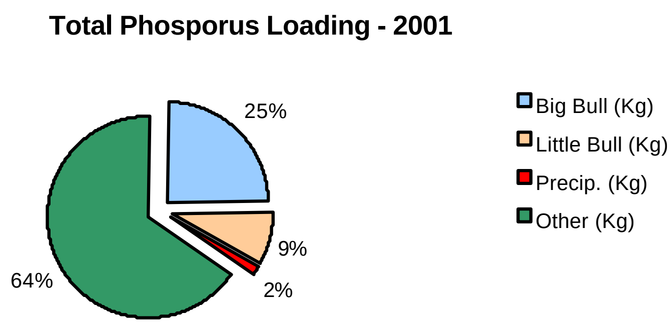


fig. 8. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

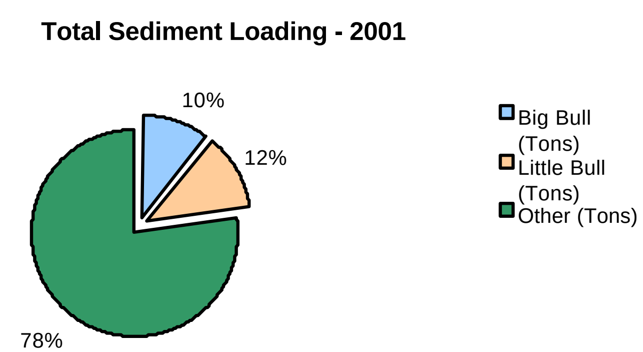


fig. 9. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Much of the sediment load from Little Bull Creek during 2001 can be attributed to low-storm flow events (for definition of low-storm flow see p. 4). More low-storm flow occurred in Little Bull Creek during 2001 than Big Bull Creek (86,572,800 ft^3 in LB vs. 80,265,600 ft^3 in BB). Possibilities for this might include: More precipitation in the LB subwatershed, more impervious surface area per the surface area of the subwatershed, and less BMPs that slow runoff and allow for infiltration of water into the ground. These conditions can lead to increased stream bank erosion and impact larger storm flow events.

Phosphorus and sediment loads are primarily transported to Hillsdale Lake during storm flow events. Therefore, composite samples taken during runoff events in 2001 are part of the decision making process when determining the project's priority subwatershed. In most cases total flow during runoff events remains lower in Little Bull Creek than Big Bull Creek. Yet, concentrations in Little Bull Creek in many cases surpass those in Big Bull Creek (**figs. 10 and 11**). The same remains true when peak flow rates are considered.

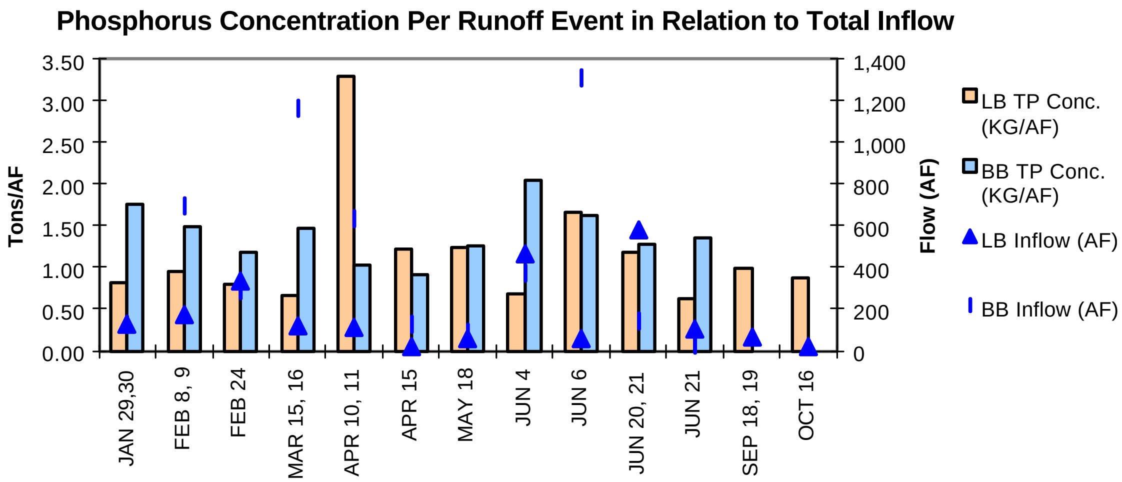


fig. 10. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

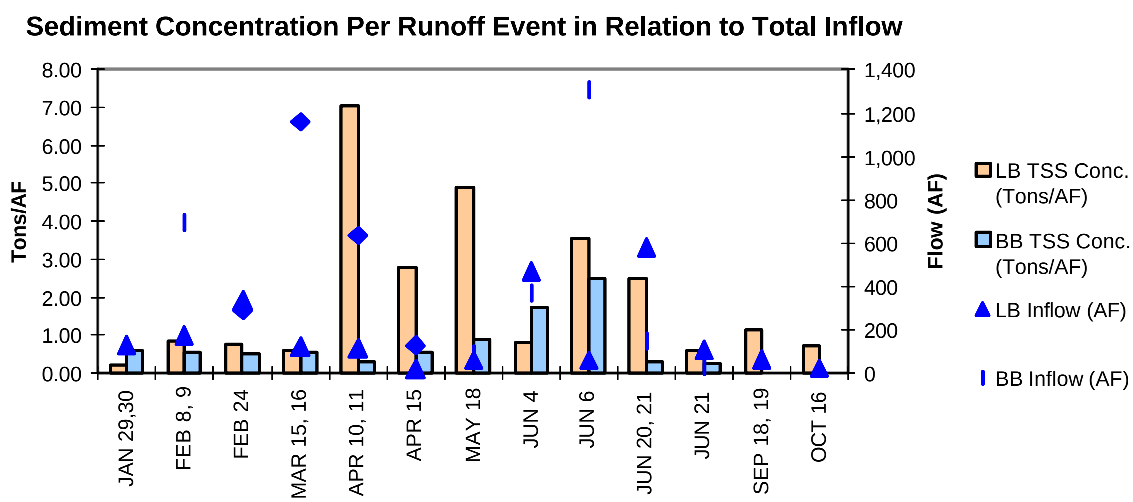
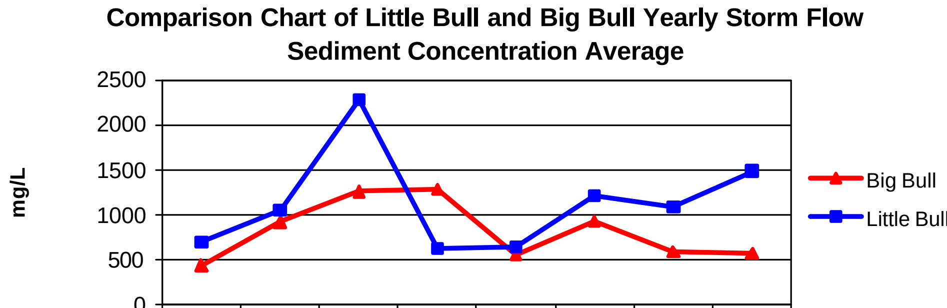


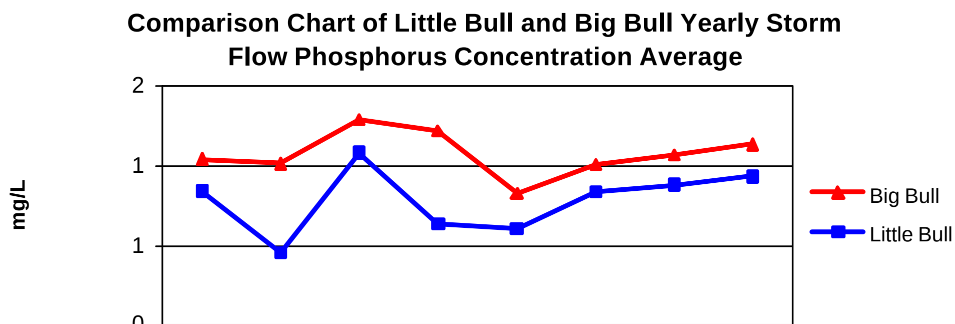
fig. 11. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

It can be noted that sediment concentrations in Little Bull Creek exceeded those in Big Bull Creek while phosphorus concentrations normally remained greater in Big Bull Creek (**figs. 10 and 11**). Though this seems anomalistic it is consistent with historic concentration levels in both creeks (**figs. 12 and 13**).



	1994	1995	1996	1997	1998	1999	2000	2001
Big Bull	440	923	1263	1291	553	928	587	573
Little Bull	700	1055	2279	628	646	1225	1087	1492

fig. 12. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.



	1994	1995	1996	1997	1998	1999	2000	2001
Big Bull	1.04	1.02	1.29	1.22	0.83	1.01	1.07	1.14
Little Bull	0.84	0.46	1.09	0.64	0.61	0.84	0.89	0.94

fig. 13. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

In 2001, the gap closed between concentration levels of phosphorus and sediment in Big Bull and Little Bull Creeks. Little Bull Creek introduced the greater total sediment load to Hillsdale Lake. Also, the Little Bull Creek Subwatershed has become increasingly more urbanized. It is also the subwatershed in which the majority of the "first-flush" sampling is taking place in 2002. Because of these reasons, it is the opinion of the Hillsdale Water Quality Project that the Little Bull Subwatershed is designated the priority subwatershed.

Project Goals

Estimates of phosphorus and sediment load reductions attributed to BMPs implemented between January 1, 1997 and December 31, 2001 also indicate that the sediment goal has been met. According to NRCS, those best management practices save 54,294.95 tons of sediment annually. While estimations provided by the NRCS are positive, this loading report provides more accurate estimates of phosphorus and sediment loads.

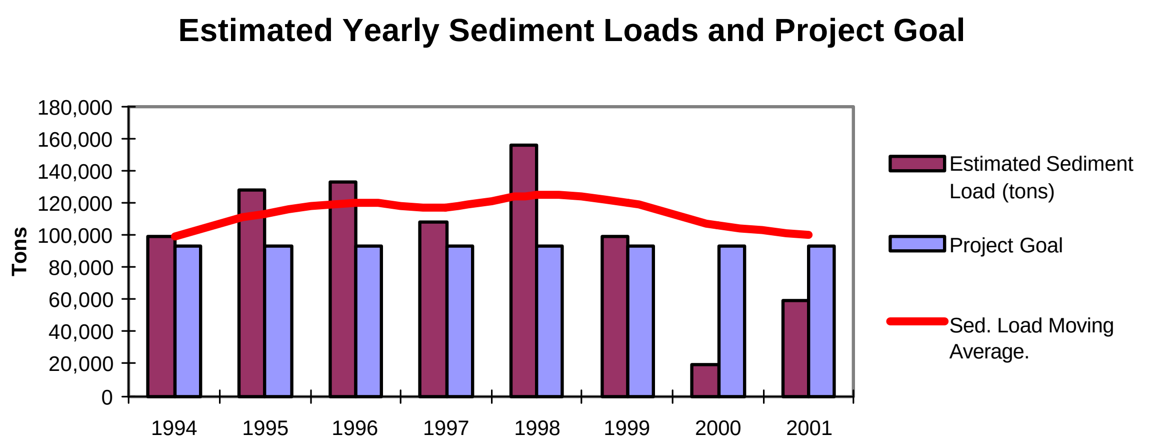


fig. 14. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

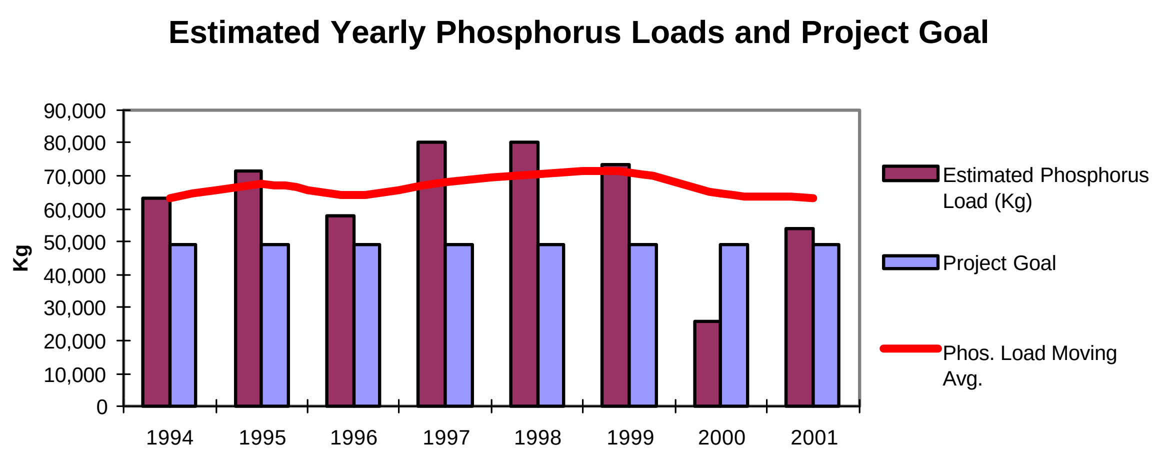


fig. 15. Graph constructed using Hillsdale Water Quality Project sampling data and USGS flow data.

Efforts made by those associated with the Hillsdale Water Quality Project have likely been good for water quality. But if the improvement is insignificant compared to the margin of error in the yearly estimations, they may not be reflected. Previous loading estimates indicate that the Project's goal of sediment reduction has been met (**fig. 14**). However, these two years also had lower than average lake inflows. This directly affected the lower sediment and phosphorus loads (**figs. 14 and 15**). Therefore, further implementation of best management practices is required to insure accomplishment of the project's goals especially during years of higher inflow.

References

-Franano, Michael D. 1997, "Hillsdale Lake Water Quality Assessment and Phosphorus Load Estimate": 1993-1996.

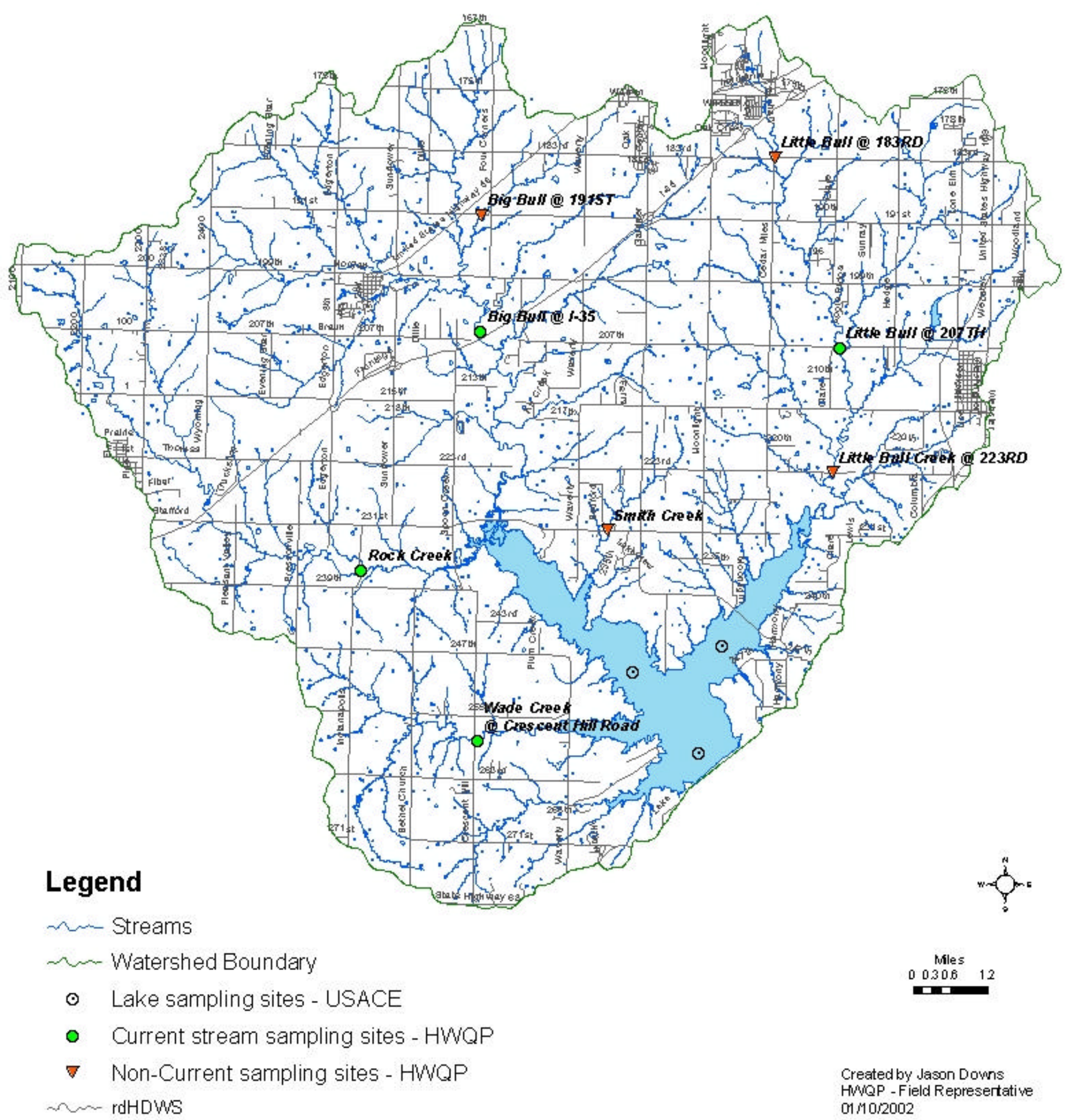
-Holt, Anthony A. 1996, "Estimation of 1994 Point Source and Non-Point Source Phosphorus Loading to Hillsdale Lake": Shawnee Mission, Kansas, Johnson County Environmental Department, various pagination.

-Jones, John R. Ph.D.   1998, "Evaluation of the Limnology of Hillsdale Lake, Kansas", Columbia, Mo., various pagination.

-Juracek, Kyle E. 1997, "Analysis of Bottom Sediment to Estimate Non-point Source Phosphorus Loads for 1981-96 in Hillsdale Lake, Northeast Kansas", Lawrence, Kansas, U.S. Geological Survey, Report 97-4235,Pg 1-55.

Supplemental Section

1993 - 2001 Hillsdale Lake Watershed Sample Locations



CALCULATIONS AND NOTES:

I. Precip. Contribution
   A. Precip Total for 2001 @ Hillsdale Lake = 37.49" = 3.12 '
   B. Phos. concentration in precip. = 0.05 mg / L
   C. Precip. volume
      1. Surface Area of Lake = 4580 acres = 199.504,300 ft^2
      2. Volume = (199,504,800 ft^2) * (3.12 ft)
      3. Volume = 622,454,976 ft^3
      4. Volume = 17,627,924,920 Liters
   D. Mass of Phos. = <u>0.05 mg / L (17,627,924,920 L)</u>
      1,000,000 mg / kg
      = **<u>881 Kg</u>**

II. Low Flow – Big Bull
   A. Avg. of 2001 Daily Mean Flow (DMF > 15 cfs) = 3.54 cfs
   B. Yearly Total Flow Volume (amt. of water that passed USGS station)
      = 3.54 ft^3 / s (60 s / min) (60 min / hr) (24 hr / day) (365 days / yr)
      = **111,637,440 ft^3**
   C. Total Low Flow Phos. (average grab concentration = 1.37 mg / L)
      = <u>111,637,440 ft^3 (28.32 L / ft^3) (1.37 mg / L)</u>
      1,000,000 mg / Kg
      = **<u>4331 Kg</u>**
   D. Total low-flow sed. (average grab concentration = 42 mg / L)
      = <u>111,637,440 ft^3 (28.32 L / ft^3) (42 mg / L)</u>
      1,000,000 mg / Kg
      = **<u>132,786 Kg</u>**

III. Low Flow – Little Bull
   A. Avg. of 2001 Daily Mean Flow (DMF > 13 cfs) = 2.32 cfs
   B. Yearly Total Flow Volume (amt. of water that passed USGS station)
      = 2.32 ft^3 / s (60 s / min) (60 min / hr) (24 hr / day) (365 days / yr)
      = **73,163,520 ft^3**
   C. Total Low Flow Phos. (average grab concentration = 0.26 mg / L)
      = <u>73,163,520 ft^3 (28.32 L / ft^3) (0.35 mg / L)</u>
      1,000,000 mg / Kg
      = **<u>539 Kg</u>**
   D. Total low-flow sed. (average grab concentration = 36 mg / L)
      = <u>73,163,520 ft^3 (28.32 L / ft^3) (36 mg / L)</u>
      1,000,000 mg / Kg
      = **<u>74,592 Kg</u>**

IV. Storm Events – Big Bull
   A. See file:

C:\WINNT\Profiles\Administrator\Personal\Field Representative\loading report\BB storm flow data\BB 2001\Storm Load BB – 2001.xls

1. Total Amt. of Phos. produced from storm events = **7,248 Kg**
2. Total Amt. of Sed. produced from storm events = **4,927,832 Kg**

V. Storm Events – Little Bull

A. See file:

C:\WINNT\Profiles\Administrator\Personal\Field Representative\loading report\LB storm flow data\LB 2001\Storm Load LB – 2001.xls

1. Total Amt. of Phos. produced from storm events = **2,328 Kg**
2. Total Amt. of Sed. produced from storm events = **3,434,421 Kg**

VI. Big Bull – Low Storm Flow – Phos.

A. Avg. low flow Phos. = 1.37 mg/L
B. Avg. low-storm flow Phos. = 0.74 mg/L
C. Combined Avg. (1.37 + 0.74 mg/L)/2 = **1.06 mg/L**
D. Total low-storm flow = **80,265,600 ft^3**
E. Phos. load for low storm flow

$$= \frac{80{,}265{,}600\ ft^3\ (28.32\ L/ft^3)\ (1.06\ mg/L)}{1{,}000{,}000\ mg/Kg}$$

= **2410 Kg**

VII. Big Bull – Low Storm Flow – Sed.

A. Avg. low flow Sed. = 41.8 mg/L
B. Avg. low-storm flow Sed. = 397 mg/L
C. Combined Avg. = **219 mg/L**
D. Total low-storm flow = **80,265,600 ft^3**
E. Sed. load for low-storm flow

$$= \frac{80{,}265{,}600\ ft^3\ (28.32\ L/ft^3)\ (219\ mg/L)}{1{,}000{,}000\ mg/Kg}$$

= **497,814 Kg**

VIII. Little Bull – Low Storm Flow – Phos.

A. Avg. low flow Phos. = 0.26 mg/L
B. Avg. low-storm flow Sed. = 1.12 mg/L
C. Combined Avg. = **0.69 mg/L**
D. Total low-storm flow = **86,572,800 ft^3**
E. Phos. load for low storm flow

$$= \frac{86{,}572{,}800\ ft^3\ (28.32\ L/ft^3)\ (0.74\ mg/L)}{1{,}000{,}000\ mg/Kg}$$

= **1691 Kg**

IX. Little Bull – Low Storm Flow – Sed.

A. Avg. low flow Phos. = 36 mg/L

B. Avg. low-storm flow Sed. = 2415 mg/L

C. Combined Avg. = **1226 mg/L**

D. Total low-storm flow = **86,572,800 ft^3**

E. Sed. load for low storm flow

$$= \frac{86{,}572{,}800\ ft^3\ (28.32\ L/ft^3)\ (1292\ mg/L)}{1{,}000{,}000\ mg/Kg}$$

= **3,005,835 Kg**

X. Unmonitored Phosphorus

A. Total inflow from Big Bull and Little Bull Creeks:

1. BB Low Flow Inflow = 111,637,440 ft^3 = 2563 acre – feet
2. BB Storm Flow Inflow = 215,012,160ft^3 = 4971 acre – feet
3. BB Low Storm Flow = 80,265,600 ft^3 = 1843 acre – feet
4. BB Total Inflow = 9377 acre – feet
5. LB Low Flow Inflow = 73,163,520 ft^3 = 1680 acre – feet
6. LB Storm Flow Inflow = 96,525,000 ft^3 = 2218 acre – feet
7. LB Low Storm Flow = 86,572,800 ft^3 = 1987 acre – feet
8. LB Total Inflow = + 5885 acre – feet

TOTAL INFLOW = **15,262** acre – feet

B. Storm Phos. Load – Unmonitored portion of Watershed

1. 50% of [(Total Lake Inflow) – ((BB total inflow) + (LB total inflow))]

= 0.5[(43,971 acre – ft *) – (15,225 acre – ft)] = 14,373 acre – ft
= 626,087,880 ft^3

2. $$\frac{626{,}087{,}880\ ft^3\ (1.14\ mg/L^{**})\ (28.32\ L/ft^3)}{1{,}000{,}000\ mg/Kg} = 20{,}213\ Kg$$

C. Unmonitored low flow

1. 0.33 [(43,971 acre – ft) – (13,320 acre – ft)] = 10,115 acre – ft
= 440,609,400 ft^3

2. $$\frac{440{,}609{,}400\ ft^3\ (28.32\ L/ft^3)\ (0.72\ mg/L)}{1{,}000{,}000\ mg/Kg} = 8984\ Kg$$

D. Unmonitored low – storm flow

1. 0.17 [(43,971 acre – ft) – (13,320 af) = 5,210 af = 226,991,160 ft^3

2. $$\frac{226{,}991{,}160\ ft^3\ (28.32\ L/ft^3)\ (0.85\ mg/L)}{1{,}000{,}000\ mg/Kg} = 5{,}464\ Kg$$

E. Total Phosphorus Load from Unmonitored

Storm Load =	20,213 Kg
Low Flow Load =	8,984 Kg
Low Storm Flow Load =	+ 5,464 Kg
	34,661 Kg

XI. Unmonitored Sediment

A. Total Inflow from BB & LB = 15,225 acre – ft.

B. Storm Sed. Load

1. 0.5 [(58,261* af) – (15,225 af)] = 21,518 af

= 937,324,080 ft^3

2. **978,324,080 ft^3 (28.32 L/ft^3) (1206 mg/L) = 33,413,602 Kg**
   1,000,000 mg/Kg

C. Unmonitored Low Flow

1. **0.33 [(58k,261 af) – 13,320 af)] = 14,831 af**
   = 646,038,860 ft^3
2. **646,038,360 ft^3 (28.32 L/ft^3) (38 mg/L) = 695,241 Kg**
   1,000,000 mg/Kg

D. Unmonitored Low – Storm Flow

1. **0.17 [(58,261 af) – (13,320 af)] = 7,640 af**
   = 332,798,400 ft^3
2. **332,798,400 ft^3 (28.32 L/ft^3) (759 mg/L) = 7,153,462 Kg**
   1,000,000 mg/Kg

E. Total Sediment Load from Unmonitored

Storm Load =	33,413,602 Kg
Low Flow Load =	695,241 Kg
Low Storm Flow Load =	+ 7,153,462 Kg
	41,262,305Kg

XII. Total Phos. Load for Hillsdale Lake 2001 =

1. Total Phos. – Precip =	881 Kg
2. Total Phos. – Storm BB =	7,248 Kg
3. Total Phos. – Low Storm BB =	2,410 Kg
4. Total Phos. – Low Flow BB =	4,331 Kg
5. Total Phos. – Storm LB =	2,328 Kg
6. Total Phos. – Low Storm LB =	1,691 Kg
7. Total Phos. – Low Flow LB =	539 Kg
8. Total Phos. – Unmonitored =	+ 34,661 Kg
	54,089 Kg

XIII. Total Sed. Load for Hillsdale Lake 2001 =

1. Total Sed. – Precip =	0 Kg
2. Total Sed. – Storm BB =	4,927,832 Kg
3. Total Sed. – Low Storm BB =	497,814 Kg
4. Total Sed. – Low Flow BB =	132,786 Kg
5. Total Sed. – Storm LB =	3,434,421 Kg
6. Total Sed. – Low Storm LB =	3,005,835 Kg
7. Total Sed. – Low Flow LB =	74,592 Kg
8. Total Sed. – Unmonitored =	+ 41,262,305Kg
	53,335,585 Kg