COST OF PHOSPHORUS REMOVAL AT WISCONSIN PUBLICALLY-OWNED TREATMENT WORKS

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EXECUTIVE SUMMARY

This report presents the result of a study to estimate the cost of providing capacity at publically-owned treatment works (POTWs) in Wisconsin to reduce effluent phosphorus concentrations to meet the water quality standards required in NR 217 of the Wisconsin Administrative Code. This study evaluated 217 POTWs that discharge treated effluent to surface water. The estimated cost of providing phosphorus removal at these treatment systems over the next 10 years is $702,305,000 in 2012 dollars. A state wide estimated for all surface water dischargers can be extrapolated from the data generated during this study. The extrapolated total cost of phosphorus removal in Wisconsin could be as high as $1.35 billion, but more likely is in the range of $860 million to $953 million.

1.0 INTRODUCTION

Due to the documented adverse water quality issues caused by phosphorus in surface waters, the Wisconsin Department of Natural Resources (WDNR) has limited the effluent phosphorus concentration in discharges from publically-owned treatment works (POTW) to 1.0 mg/l. Implementation of the regulatory requirements has been through the dischargers' Wisconsin Pollutant Discharge Elimination System (WPDES) permit. There are limited exemptions to this requirement for small communities and dischargers of less than 150 pounds of phosphorus per month.

Responding to national objectives set by the U.S. Environmental Protection Agency (USEPA), the WDNR revised Ch. 217 of the Wisconsin Administrative Code in 2010 to require more stringent effluent phosphorus limits in POTW discharges. As before, the new administrative code and discharge requirements includes exemptions and variances for small communities.

This study was undertaken to estimate site-specific capital costs of providing the treatment capacity at POTWs for the removal of phosphorus in compliance with the new discharge requirements. This study looked at POTWs only; privately-owned wastewater treatment systems such as those serving mobile home parks, privately-owned campgrounds, and nursing homes were not included in this study.

2.0 DESCRIPTION OF STUDY

2.1 Project Work Plan

The first work component of this study was the development of a project work plan which was used to guide the study effort in a logical sequence of work tasks. The work plan called for the following activities:

- Literature Search
- Development of cost curves for estimating phosphorus removal costs
- Assumed phosphorus effluent limitations for dischargers based on watersheds
- Estimation of discharger-specific phosphorus removal costs
- Record keeping

Each of these work activities is discussed below.

2.2 Literature Review

An internet-based literature search was conducted for the purposes of identifying treatment technologies for the removal of phosphorus from wastewater, the removal efficacy of various treatment technologies, and costs associated with phosphorus removal. A listing of the literature obtained and reviewed is contained in the Bibliography.

2.3 Development of Cost Curves

3.2.1 CAPDETWorks Software

Initially, the work plan suggested that a series of cost curves based on the literature and cost information obtained from the Environmental Loans Oracle System (ELOS) database would be developed to assist with the evaluation of site-specific phosphorus removal costs based in individual treatment systems, treatment design capabilities, and treatment system performance. However this approach was abandoned early in the study based on cost curves contained in the 2008 EPA Municipal Nutrient Removal Technologies Reference Document (*Shin 2008*). These costs curves for nutrient removal, including phosphorus and nitrogen removal, were developed by the USEPA using available software called CAPDETWorks. CAPDETWorks was initially developed by the USEPA in conjunction with the US Army Corps of Engineerd. It has since been purchased, and is maintained, by Hydomantis Environmental Software Solutions, Inc., Hamilton, Ontario, Canada.

CAPDETWorks is a planning software which allows rapid cost estimates and comparisons of various treatment trains when planning for new or upgraded treatment works. The software allows the designer to construct a treatment facility schematic showing individual treatment units. It also allows input of influent and effluent flow characteristics, unit operating parameters, and selection of equipment, cost, and financial indices. The software then calculates the number and size of the treatment units and calculates the capital costs, annual O&M costs, annual chemical and energy costs, and total present worth of the conceptual schematic.

Based on the USEPA and manufacturer's description of the software, it was determined that CAPDETWorks would be a suitable for estimating phosphorus removal costs in Wisconsin. Use of the software eliminated the need to develop cost curves and provided a greater degree of certainty to the cost estimates.

3.2.2 Cost Comparison Study

Hydromantis claims the CAPDETWorks software will estimate the construction cost of treatment plants to within ± 20%. The EPA Municipal Nutrient Removal Technologies Reference Document Volume I (*Shin 2008*)) contains case studies of 20 treatment systems including the actual costs of construction and operation. The actual costs from the case studies are compared to CAPDETWorks estimates for identical treatment works. The comparisons demonstrated that the construction costs estimated by CAPDETWorks were within the claimed 20% margin.

A small cost comparison of CAPDETWorks estimates to actual treatment facility costs in Wisconsin was done to validate the use of CAPDETWorks for this phosphorus removal cost study. Using wastewater Facility Plans and Plan and Specification approvals and construction contract records maintained by the Bureau of Community Financial Assistance, actual treatment facility construction costs were compared to CAPDETWorks estimates for six communities. The following table shows a summary of the results of this cost comparison.

TABLE 2.1
Cost Comparison Summary

COMMUNITY	COST DATUM	CAPDETWorks ESTIMATE	ACTUAL CONSTRUCTION COST	DIFFERENCE
Bayfield	July, 2000	$220,000	$199,600	10%
Edgar	April, 2009	$560,000	$491,800	14%
Lake Mills	April, 2001	$910,000	$1,010,529	11%
Viroqua	April, 2002	$1,300,000	$1,448,600	11%
Warrens	June, 2005	$2,530,000	$2,873,000	14%
Waupun	October 2002	$4,500,000	$4,686,000	4%

Consistent with the results found by the USEPA, this cost comparison found that the CAPDETWorks estimates were within ±15% of actual costs. As the study progressed, when facilities planning cost data or actual construction data was available, the CAPDETWorks estimate was compared to that cost information as a continuing validation of the CAPDETWorks costing accuracy. For example it was found that the CAPDETWorks estimate for the City of Rhinelander was $16,619,000; actual construction contract costs were $16,710,080, a difference of less than 1.0%. In 2008 the Bristol Utility District provided the Department with an estimate for phosphorus removal of $2,381,000. This 2008 cost is within 15% of the 2012 CAPDETWorks cost estimate of $2,727,000 (*personal communication Becky Scott; September 29, 2012*).

2.4 Assumed Effluent Limits

Early in this study, the Bureau of Watershed Management provided a categorized list of the major river watersheds in Wisconsin. A category designation was assigned to each watershed based on phosphorus loading, assimilative capacity, and available phosphorus stream data. Category 1 watersheds consisted of those river basins where surface water quality consistently meets phosphorus water quality standards and criteria. Category 2 watersheds were those where some streams within the watershed meet phosphorus water quality standards and some streams exceed the phosphorus water quality standards. Category 3 watersheds were those where water quality consistently exceeds phosphorus water quality standards and criteria.

There are 131 POTWs in Category 1 watersheds, 198 POTWs in Category 2 watersheds, and 202 POTWs in Category 3 watersheds.

For this study, it was assumed that dischargers in the Category 1 watersheds would not be required to improve phosphorus removal and no change, or limited changes, in current permitted phosphorus discharge limitations would be likely to occur. For Category 2 dischargers it was assumed that some changes in phosphorus discharge limits are likely. For the Category 2 watersheds, it was assumed that the upper 50% of the dischargers (based on influent flow rate and total phosphorus loading) would have to meet a 0.1 mg/l phosphorus limit; the remaining dischargers would have to meet a 0.5 mg/l limit. For the category 3 watersheds it was assumed that all dischargers in the watershed would be required to meet very stringent phosphorus limits of 0.05 mg/l.

There were two exceptions to the assumed phosphorus limitations. Lagoon systems would have an assumed discharge limit of 1.0 mg/l. Finally, it was assumed that any direct discharge to the Great Lakes would have to meet a 0.5 mg/l effluent limit.

These effluent limit assumptions were adjusted, however, for dischargers within the Lower Rock River watershed and the Lower Fox River watershed to recognize the potential limits that are being determined through the Total Maximum Daily Loading (TMDL) studies that have been approved for these two watersheds. In these instances, Jim Baumann of the Bureau of Watershed Management suggested specific effluent limits for these dischargers. For the most part, the suggested limits varied from 0.075 mg/l to about 0.2 mg/l.

The assumed effluent limit for each POTW evaluated in this study is shown on the summary list contained in Appendix A.

2.5 Estimating Discharger-Specific Phosphorus Removal Costs

2.5.1 Technology Applications for Various Levels of Phosphorus Removal

Based on the treatment descriptions and efficacies gleaned from the literature, the following conceptual treatment trains were assumed for each level of phosphorus removal needed to achieve the assumed phosphorus effluent limits discussed above.

- Effluent Standard: 1.0 mg/l: Standard activated sludge process.
- Effluent Standard: 0.5 mg/l: Enhanced Biological Phosphorus removal with mult-point chemical injection and enhance biosolids handling.
- Effluent Standard: 0.1 mg/l: Enhanced Biological Phosphorus removal with rapid mix and flocculation chemical addition followed by sand filtration with enhanced biosolids handling.
- Effluent Standard: 0.05 mg/l: Enhanced Biological Phosphorus removal with rapid mix and flocculation chemical addition followed by advance filtration with enhanced biosolids handling.

During the course of the study, the noted conceptual treatment trains were considered to be upgrades and made to fit with the existing treatment works. The evaluation of each individual POTW was very brief and the practicalities of the assumed upgrades were not evaluated. In reality, for some treatment systems a more detailed analysis might find it more cost-effective to replace an aging treatment system with a new system specifically designed for phosphorus reduction rather than retrofitting with upgraded unit treatment processes to improve phosphorus reduction from the waste stream.

The stated treatment process assumptions were modified slightly through the course of this study. For example for communities served by a lagoon treatment system, the lagoon system was not replaced with an activated sludge system as would be suggested by the treatment requirements noted above. Instead, chemical addition and settling units were added to the treatment schematic following the lagoon(s) and prior to disinfection and discharge. Likewise, standard activated sludge treatment systems were assumed to be capable of being operated in an enhanced biological phosphorus removal manner and the additional needed phosphorus removal was achieved strictly through chemical addition, coagulation / flocculation, and subsequent filtration. However, in a couple of instances, e.g. Forest Junction Sanitary District, the Town of Plymouth Sanitary District #1, and the Wrightstown Sanitary District #2, a new treatment system was assumed over retrofitting the existing wastewater facility when it was perceived that a new system would be required to meet stringent effluent limits as determined by TMDL.

2.5.2 Costing Methodology

The estimated capital cost of phosphorus removal was calculated by (1) estimating the year 2010 construction cost of the existing treatment system; (2) estimating the year 2010 cost of the upgraded treatment system; and (3) subtracting the cost of the existing system from the cost of the upgraded system. With the exception of the City of Waukesha, all costs were estimated using the CAPDETWorks software. Costs for phosphorus removal for Waukesha were taken from a May 2011 Facilities Plan for Waukesha prepared by Strand Associates, Madison, Wisconsin.

2.5.3 Information Used in Estimating Discharger Specific Phosphorus Removal Costs

For the most part, technical and regulatory information used in evaluating individual treatment plant performance was obtained from the Department's System for Wastewater Applications, Monitoring and Permits (SWAMP) database. This information included influent and effluent data, treatment system design information, treatment facility description, and the current WPDES discharge permit. In cases where information was not available – or only partially available – from SWAMP, other sources of information were consulted included discharger websites, regional planning commission documents (obtainable on line), Department district staff, and direct communications with treatment plant operators, engineers, or directors of public works.

Current (2010) service populations were generally obtained from population projections prepared by the Wisconsin Department of Administration (*WDOA 2010*). Year 2022 populations were estimated by extrapolation. In cases of larger regional treatment systems the estimated service populations were based on the individual populations of the municipalities or communities projected by the DOA population document. For dischargers such as sanitary districts or unincorporated population centers where the current service population was not available from the DOA data, population estimates were obtained from online sources such community websites, city/county census data, or regional planning documents.

2.5.4 Evaluation of Treatment System Performance

For each treatment facility, the treatment system performance was evaluated based on the five-year influent and effluent monitoring record. For cost estimates done early in the study beginning in 2011, the influent and effluent records for the years 2006 through 2010 were downloaded from SWAMP. Beginning in January 2012, influent and effluent records for the years 2007 through 2011 were used.

Evaluation of treatment plant performance included:

- 5-year monthly average and monthly average peak influent flow rates versus design flow rates;
- Current BOD5 and total suspended solids loading (lbs/day) versus design loading;

- Current phosphorus and ammonia nitrogen loading (lbs/day) (when available otherwise influent PO4 and NH3 concentrations were assumed to be 8.0 mg/l and 28.0 mg/l, respectively) versus design loadings;
- 5-year monthly average BOD5 effluent concentrations versus permit limitations;
- 5-year monthly average total suspended solids (TSS) effluent concentrations versus permit limitations;
- 5-year average phosphorus effluent concentrations versus permit limitations; and
- 5-year average ammonia nitrogen effluent concentrations versus permit limitations.

While this study was focused on the costs of upgrading treatment systems to meet assumed effluent phosphorus limits, when other monitoring data indicated that the system also needed upgrading to improve hydraulic capacity and/or BOD_5, TSS, and NH_4 removal to meet permit limits, the cost of the needed upgrades were also calculated. When a system upgrade was evaluated, the design conditions for the upgrade were assumed for the year 2022 based on population growth estimates.

2.5.5 Working with CAPDETWorks

As previously noted, CapdetWorks is cost-estimating software that allows rapid facility planning-level cost evaluation of wastewater treatment systems. CAPDETWorks is based on the CAPDET cost estimating model developed in the early 1970s by the U.S. Army Corps of Engineers for the USEPA. The Capdet model used cost curves developed for standard wastewater treatement system unit processes. Hydromantis has improved the CAPDET model by adding more standard treatment process units and incorporated algorithms and statistically generated cost curves based on average cost and specified design and operational parameters. CAPDETWorks Version 2.5, purchased in April 2011 was used for this study.

CAPDETWorks provides default design parameters for each unit treatment process. These defaults can be overridden, however, by the software user allowing estimates based on specific influent characteristic, unit process parameters, and effluent goals. For the most part, the default parameters provided by the software were accepted for this study. Exceptions were made, however, to input specific influent and system design information, and minor changes to some unit processes to match design requirements specified in Wisconsin Administrative Code Chapter NR 110.

CAPDETWorks allows manipulation of various unit cost information used in making the treatment facility cost estimate. Unit Costs include construction and material costs, labor costs, chemical costs, financial factors such as interest rate, length of construction, and the operating life of the treatment facility. CAPDETWorks includes in it’s calculations other costs such as mobilization, site preparation, site electrical, yard piping, instrumentation and controls, lab and administration building, contractor profit, legal costs, engineering fees, contingency, and land. The CAPDETWorks default values for each financial parameter can also be overridden by the software user by substituting alternate values.

CAPDETWorks cost estimates are based on one of three equipment cost databases: USA Average July 1977, USA Average July 2000, and USA Average September 2007. In addition, the software allows adjustment of three construction indices: Engineering News Record (ENR), Marshall and Swift (M&S), and the pipes, valve, and fitting (PIPE) component of the Chemical Engineering Plant Cost Index. These indexes allow an estimate of the changes in equipment and other construction costs over time and are used to update cost estimates from one point in time to another point in time. The following table shows adjustments made to the default costing parameter for this phosphorus removal cost study.

TABLE 2.2
CAPDETWorks COSTING PARAMETERS

COST PARAMETER	CAPDETWorks DEFAULT VALUE	ADJUSTED VALUE USED FOR PHOSPHORUS COST STUDY
Equipment Cost Database	September, 2007	September, 2007
Cost Indices	ENR Construction Index: 7930.8 Marshall & Swift: 1383.6 Chemical Engineering PIPE Index: 738.8	Adjusted to average year 2010 value: 8802.4 Adjusted to December 2010 value: 1457.4 Adjusted to December 2010 value: 819.04
Financial Parameters - Interest - Construction Period - Operating life of plant	 8% 3 years 40 years	 Adjusted to February 2010 discounted rate value: 0.75% 1 year for influent flow rate <0.1 mgd 2 years for influent flow rate >0.1, <1.0 mgd 3 years for influent flow rate >1.0., <10.0 mgd 4 years for influent flow rate >10 mgd 40 years.
Other Costing Parameter - Miscellaneous Costs - Legal Costs - Engineering Design Fee* - Inspection Costs* - Contingency* - Other Technical Costs* - Contractor Profit	 5% 2% 15% 2% 10% 2% 15%	 5% 2% 0% 0% 0% 0% 15%
Cost of Land	$20,000 / acre	$0 / acre (land ignored)

* Note: Engineering / technical / inspection and contingencies were calculated separately based on the CapdetWorks cost estimate. Engineering fees were calculated at 20% and contingency allowance was calculated at 10%.

Output from CAPDETWorks includes the estimated construction cost, annual operation and maintenance costs; annual material, chemical and energy costs; and the total present worth of the system based on the either the CAPDETWorks default financial values or those selected by the user. For the purpose of this cost study only the construction costs estimates were useful.

2.6 Record Keeping

Results of this study were compiled and maintained in a Microsoft Excel 2010 spreadsheet database. The database included a summary tab which showed basic information about each discharger, the presumed phosphorus effluent limit used in the cost estimate, the estimated capital costs, engineering costs, and contingency costs. As discussed above, costs were estimated in 2010 dollars, but have been converted to 2012 dollars using the January 2012 Engineering New Record (ENR) construction cost index.

The project database also included a separate tab for each discharger. The discharger tabs were based on a standardized worksheet that included individual tables for summarizing the 5-year influent and effluent data, permit discharge limit information, calculation of reserve capacity of the treatment system. Each tab also contained work areas for a description of the existing treatment system, present system performance, and a description of upgrades necessary to meet the assumed phosphorus effluent limit; visual presentation of the existing and upgraded treatment system schematic diagrams, and estimated unit process costs obtained from CAPDETworks.

3.0 DISCUSSION OF RESULTS

3.1 Estimated Capital Costs of Phosphorus Removal

There are 530 permitted POTW surface water dischargers in the State of Wisconsin. Two hundred and seventeen of these (41%) were evaluated during this phosphorus removal cost study. Twenty-two of the evaluated POTW surface water dischargers were found not to require phosphorus removal upgrades based on current treatment performance and the assumed phosphorus effluent limits. For the remaining 195 facilities, phosphorus removal costs (including engineering and contingency) ranges from $164,000 for the Village of Cascade (design population 670 persons) to $161,117,000 for the Milwaukee Metropolitan Sewerage District Jones Island Treatment Facility (design population 652,100). The total estimated capital cost of phosphorus removal for these 195 facilities is $702,305,000. All costs are in January 2012 dollars.

The following table shows the range of estimated costs and total costs for groupings of assumed effluent phosphorus concentrations.

TABLE 3.1
PHOSPHORUS REMOVAL COSTS BY EFFLUENT GROUP

EFFLUENT PHOSPHORUS CONCENTRATION	NUMBER OF EVALUATED FACILITIES IN EFFLUENT GROUP	LOWEST COST	HIGHEST COST	TOTAL COST FOR EFFLUENT GROUP
<0.1 mg/l	146	$466,000	$161,117,000	$547,684,000
0.1 to <0.5 mg/l	25	$465,000	$25,809,000	$143,005,000
0.5 to <1.0 mg/l	24	$164,000	$580,000	$11,616,000
TOTALS	**195**			**$702,305,000**

An alphabetical listing of the POTWs evaluated in this study is contained in Appendix A.

3.2 Data Charts

Appendices B To D contain data graphs showing the study results is various visual presentations. Appendix B contains the charts for the <0.1 mg/l effluent group. Appendix C contains the charts for the 0.1 to <0.5 mg/l effluent group. And Appendix D contains the charts for the 0.5 to <1.0 mg/l group. Following are descriptions of the data graphs.

- Graphs B.1, C.1, and D.1 show the Capital Cost of phosphorus removal versus the design Influent Flow Rate for each effluent group.

- Graphs B.2, C.2, and D.2 show Capital Cost versus Design Population.
- Graphs B.3, C.3, and D.3 show the unit Per Capita Cost versus Design Population.
- Graphs B.4, C.4, D.4 show the unit Phosphorus Removal Capital Cost (dollars/pound phosphorus removed per day) versus the Design Population.
- Graphs B.5, C.5, D.5 show the Capital Cost versus Influent Phosphorus Loading (lbs/day)
- Graphs B.6, C.6, D.6 show the unit Phosphorus Removal Capital Costs versus the Influent Phosphorus Loading.

Because of the large variations in costs and facility sizes of the surface water discharges evaluated in this study, all the data graphs are shown on logarithmic scales. Each data graphs shows the best fit line for the data as determined by the Excel software. The formula for each line and the coefficient of determination is shown on each graph. These lines constitute cost curves that would allow the calculation of capital costs or unit capital costs when only the population, influent flow rate, or influent phosphorus loading is known.

As a group these graphs show that the capital cost of phosphorus removal increases with increasing population, influent flow rate, and influent phosphorus loading. The rate of increase of the capital costs is asymptotic and the slope of the curve of the best fit line approaches zero for very large facilities.

When expressed in unit costs of dollars per pound phosphorus removed per day, this study keenly illustrates the economies of scale at play between the phosphorus removal costs for small communities versus those for large discharges. The unit cost of phosphorus removal varied from about $3.8 million per pound phosphorus removed per day at a treatment facility with a design service population of about 140 people (Wrightstown Sanitary District #2) to about $11,300 per pound phosphorus removed per day at a treatment facility with a design service population of about 11,500 persons (City of Monroe). For the Milwaukee Metropolitan Sewerage District Jones Island Treatment facility (design service population: 652,100) the unit cost is estimated to be $31,800 per pound phosphorus removed per day. The unit rate for the Madison Metropolitan Sewerage District (design service population: 379,100) is $20,800 per pound phosphorus removed per day.

When describing the unit phosphorus removal cost for a given POTW, the influent phosphorus mass in pounds per day is calculated based on the assumed design influent flow rate (in million gallons per day) and either the known or assumed influent phosphorus concentration (in mg/l). Likewise the effluent mass loading is calculated based on the assumed design flow rate and the assumed phosphorus effluent limit for that POTW.

3.3 Extrapolated Statewide Phosphorus Removal Cost

The phosphorus removal costs estimated by this study are not the entire picture, however, because only 41% of the permitted POTW surface water dischargers were evaluated. Of the 217 POTWs evaluated, cost estimates were made for all 202 Category 3 watershed POTWs (watershed categories were previously defined in Section 2.4 of this report). However, time permitted evaluation of only 15 Category 2 POTWs; no Category 1 POTWs were reviewed. Using the data from Table 3.1, it is possible to extrapolate an estimate of the state wide cost of phosphorus removal by multiplying the average cost of phosphorus removal for each effluent grouping shown in Table 3.1 by the total number of dischargers which fall into that effluent category. The results of this extrapolation are shown in Table 3.2. Note that the number of facilities listed for the 0.1 to <0.5 mg/l group includes both one-half of the Category 2 watershed dischargers and 33 dischargers from the Category 3 watersheds which were determined would have less stringent effluent limits based on TMDL studies than the 0.05 mg/l phosphorus limit assumed for that watershed category. The number of dischargers shown for the 0.5 to <1.0 mg/l effluent group consists of the other half of the Category 2 watershed dischargers. It is assumed that there is no costs or only marginal costs associated with phosphorus removal for the Category 1 watershed dischargers.

TABLE 3.2
ESTIMATED STATEWIDE COST OF PHOSPHORUS REMOVAL

EFFLUENT PHOSPHORUS CONCENTRATION	TOTAL NUMBER OF FACILITIES IN EFFLUENT GROUP	AVERAGE COST OF PHOSPHORUS REMOVAL FOR EFFLUENT GROUP	TOTAL COST FOR EFFLUENT GROUP
<0.1 mg/l	146	$3,752,000	$547,684,000
0.1 to <0.5 mg/l	132	$5,720,200	$755,066,400
0.5 to <1.0 mg/l	99	$484,000	$47,916,000
TOTALS	**377**		**$1,350,666,000**

[Note: 377 facilities + 22 no cost facilities + 131 Category 1 watershed dischargers = 530 facilities]

This extrapolated value is skewed, however, because of the higher average cost for the 0.1 to < 0.5 mg/l effluent group when compared to the average cost for the <0.1 mg/l group. The data statistics presented in Appendix E show that the 25 dischargers in the 0.1 to <0.5 mg/l effluent group were, as a group, larger facilities than the 146 facilities in the <0.1 mg/l effluent group. Since the cost of phosphorus removal is a function of both technology cost to meet effluent requirements and facility size, the costs associated with the facility size make up for the less sophisticated technologies needed to meet the less stringent effluent limits of the 0.1 to <0.5 mg/l group.

Given that the 25 facilities evaluated in the 0.1 to <0.5 mg/l group is only 20% of the total number of facilities in that effluent group, it is reasonable to expect that if all facilities in this effluent group were evaluated, the average cost of phosphorus removal would decrease and ultimately be less than the average for the <0.1 mg/l effluent group. If it is assumed that the average cost of phosphorus removal for the 0.1 to <0.5 mg/l group is somewhere between the average cost of the <0.1 mg/l group and the last effluent group, the expected average cost would be in the range of $2,000,000 to $2,500,000 for each facility. Based on this, the extrapolated cost of the 0.1 to <0.5 mg/l effluent group would range from $264,000,000 to $330,000,000. Using assumption, the total capital cost of phosphorus removal in Wisconsin would range from $859,600,000 to $925,600,000.

4.0 STUDY ASSUMPTIONS

Following is a listing of assumptions used when making the CAPDETWorks cost estimates for phosphorus removal.

1. When available design information did not specify the minimum and maximum flow influent flow rates, the minimum flow was generally estimated to be about 10% of the average design. The design maximum flow was assumed to be proportionately equal to the current 5-year maximum flow/average flow rates.

2. Unless otherwise known from influent monitoring or from design reports, design influent phosphorus loading is assumed to be 8.0 mg/l.

3. Monitoring data occasionally showed a value of zero for reported data. In these cases the zero entry was not considered with determining annual average values for the monitored parameters.

4. Financial information:
   - Discounted Interest Rate = 0.75% (February, 2010)
   - Marshal & Swift Cost Index = 1457.4 (Dec. 2010)
   - Engineering News Record Index = 8802.4 (Dec. 2010)
   - Chemical Engineering PIPE Index = 819.5 (projected Dec. 2010)

5. Land Costs were not included in the CAPDETWorks cost estimates.

6. When permit limits vary by season, the most stringent effluent limits was used in the CAPDETWorks estimate.

7. Some communities are required by permit to monitoring and report effluenCBOD5 instead of BOD5. These same communities generally are required to monitor and report influent BOD5. This made determination of the reserve capacity of treatment system difficult. In these cases, the reported effluent CBOD5 concentrations were considered to equal to BOD5 for the purpose of calculating the BOD5 removal efficacy. Equating the CBOD and BOD values in this manner results in the reserve capacity of the treatment system to be understated.

8. CAPDETWork process and equipment design defaults were used unless specific design information was known. Known operating conditions such as design flow rates, design BOD5 and suspended solids loadings, and effluent limits were used.

9. CAPDETWorks default design parameters for clarifier and settling tanks were changed to matchNR110.18, Wis. Adm. Code requirements.

10. Unless specifically known from available treatment facilities description, it was assumed the all treatment facilities are equipped with influent pump stations. Influent pump stations were

assumed to be equipped with constant speed pumps. Smaller system (<0.1 mgd) were assumed to be equipped with two pumps, systems with design influent rates between 0.1 and 0.5 mgd were assumed to be equipped with three pumps. Larger systems were assumed to be equipped with four pumps for influent flow rates between 0.5 and 1.0 mgd, and facilities larger than 1.0 mgd were equipped with five pumps.

11. The project Work plan called for sand filtration for treatment facilities meeting a 0.1 mg/l effluent phosphorus limitation while advanced filtration would be required for systems meeting a more stringent effluent phosphorus limit of <0.1 mg/l. Unfortunately, CAPDETWorks provided effluent limits for sand filtration and does not contain cost information for advanced filtration equipment and thus was non-distinguishing for the two effluent conditions. A difference was forced, however, by reducing the allowable hydraulic loading rate to the sand filters for systems meeting <0.1 mg/l effluent phosphorus and a larger hydraulic loading rate for those facilities meeting 0.1 mg/l. This resulted in large sand filters and thus a higher cost of filtration equipment for the more stringent effluent situation.

12. Unless otherwise specified, alum addition was assumed for chemical precipitation of phosphorus.

13. Most Wisconsin wastewater treatment facilities dispose of treated waste biosolids by application to agricultural lands. CAPDETWorks only provides equipment cost for disposal of waste sludge by landfilling. The landfilling equipment costs were assumed to equal to the equipment costs of land application.

14. Sludge handling facilities were determined based on the current configuration of the treatment facility. For smaller facilities with aerobic digestion and storage units, the cost estimated assumed an increase in the size of these facilities based on predicted sludge generation. For larger facilities, generally using anaerobic digestion, the cost estimate assumed expanded anaerobic digestion with dewatering process to reduce sludge volume for storage and ultimate disposal.

15. For very small treatment facilities, it is assumed that the facility would not purchase sludge hauling equipment for disposing of sludge, but would have the hauling done by contract or with existing equipment. For these facilities, the equipment cost associated with sludge disposal has not been included in the CAPDETWorks cost estimate.

16. Sludge storage tanks assume where assumed to have a 180 days storage capacity. Storage tanks were assumed to be circular concrete tanks with variable sludge storage depths and a 2-foot freeboard. Tank wall and floors were assumed to be one foot thick. Tank covers were assumed to be 10% of the tank construction costs.

17. Septage receiving stations/tanks were assume to have a volume equal to 1% of design average flow and a 24-hour holding time. The calculated volume was equated to equivalent 5,000-

gallon septic tanks at an assumed cost of $6,000 per septic tank.

18. Dechlorination tanks and equipment were assumed to be 30% of the costs of chlorination tanks and equipment based on a based on a 10-minute contact time in dechlorination compared to 30 minutes for chlorination.

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APPENDIX A
LIST OF EVALUATED FACILITIES

SEWERAGE AUTHORITY	PRESUMED PHOSPHORUS EFFLUENT LIMIT FOR STUDY (mg/l)	PHOSPHORUS REMOVAL COST ESTIMATE (2012 DOLLARS) (ENR CCI: 9171.73)
Total Needs Estimate		**$ 702,305,000**
ABBOTSFORD WASTEWATER TREATMENT FACILITY	0.05	$ 1,057,000
ADAMS WASTEWATER TREATMENT FACILITY	0.05	$ 1,867,000
ALGOMA WASTEWATER TREATMENT FACILITY	0.05	$ 1,152,000
ANTIGO CITY OF	0.05	$ 1,589,000
APPLETON WASTEWATER TREATMENT FACILITY	0.200	$ 25,809,000
ARGYLE WASTEWATER TREATMENT FACILITY	0.05	$ 1,303,000
ARLINGTON WASTEWATER TREATMENT FACILITY	0.04	$ 1,155,000
ARPIN WASTEWATER TREATMENT FACILITY	1.00	$ 497,000
ATHENS WASTEWATER TREATMENT FACILITY	1.00	$ 580,000
AUBURNDALE WASTEWATER TREATMENT FACILITY	1.00	$ 527,000
BAGLEY WASTEWATER TREATMENT FACILITY	0.05	$ 759,000
BAILEYS HARBOR WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces
BARABOO WASTEWATER TREATMENT FACILITY	0.10	$ 2,311,000
BARNEVELD WASTEWATER TREATMENT FACILITY	1.00	$ 569,000
BELGIUM WASTEWATER TREATMENT FACIL	0.05	$ 907,000
BELMONT WASTEWATER TREATMENT FACILITY	0.05	$ 1,074,000
BELOIT TOWN WASTEWATER TREATMENT FACILITY	0.199	$ 1,889,000
BELOIT WASTEWATER TREATMENT FACILITY	0.204	$ 4,163,000
BENTON WASTEWATER TREATMENT FACILITY	0.05	$ 1,503,000
BLANCHARDVILLE WASTEWATER TREATMENT FACILITY	0.05	$ 1,290,000
BLENKER SHERRY SANITARY DISTRICT WWTP	0.05	$ 777,000
BLOOMINGTON WASTEWATER TREATMENT FACILITY	0.05	$ 1,192,000
BLUE MOUNDS WASTEWATER TREATMENT FACILITY	0.05	$ 938,000
BRILLION WASTEWATER TREATMENT FACILITY	0.05	$ 1,336,000
BRISTOL UTILITY DISTRICT 1	0.05	$ 2,727,000
BROKAW WASTEWATER TREATMENT FACILITY	0.05	$ 810,000
BROOKFIELD, CITY OF	0.05	$ 8,373,000
BROWNTOWN WASTEWATER TREATMENT FACILITY	1.00	$ 528,000
BURLINGTON WATER POLLUTION CONTROL	0.05	$ 5,821,000
CAMBRIDGE OAKLAND WASTEWATER COMMISSION	0.075	$ 2,011,000
CAMPBELLSPORT WASTEWATER TREATMENT FACILITY	0.05	$ 1,271,000
CASCADE WASTEWATER TREATMENT FACILITY	1.00	$ 164,000
CASCO WASTEWATER TREATMENT FACILITY	0.05	$ 699,000
CASSVILLE WASTEWATER TREATMENT FACILITY	0.05	$ 1,978,000
CEDAR GROVE WASTEWATER TRTMNT FACIL	0.05	$ 1,473,000
CEDARBURG WASTEWATER TREATMENT FACILITY	0.05	$ 4,453,000
CHILI WASTEWATER TREATMENT FACILITY	1.0	$ 554,000
CHILTON WASTEWATER TREATMENT FACILITY	0.05	$ 2,765,000
CHIPPEWA FALLS WWTP	0.10	$ 8,833,000
CLARKS MILLS SANITARY DISTRICT	1.00	$ 458,000
CLEVELAND WASTEWATER TREATMENT FACILITY	0.50	$ 515,000
CLINTON WASTEWATER TREATMENT FACILITY	0.082	$ 578,000

COLBY CITY WWTF	0.05	$	1,687,000
CONSOLIDATED KOSHKONONG SANITARY DIST WWTF	0.431	$	637,000
CUBA CITY WASTEWATER TREATMENT FACILITY	0.05	$	1,553,000
DARLINGTON WASTEWATER TREATMENT FACILITY	0.05	$	1,302,000
DEERFIELD WASTEWATER TREATMENT FACILITY	0.075	$	1,937,000
DELAFIELD HARTLAND POLLUTION CONTROL COMM	0.127	$	8,959,000
DENMARK WASTEWATER TREATMENT FACILITY	0.05	$	1,583,000
DICKEYVILLE WASTEWATER TREATMENT FACILITY	0.05	$	1,168,000
DODGEVILLE WASTEWATER TREATMENT FACILITY	0.05	$	2,460,000
DOUSMAN WASTEWATER TREATMENT FACILITY	0.127	$	1,394,000
EAGLE LAKE SEWER UTILITY	0.05	$	1,385,000
EAGLE RIVER CITY OF	1.0	No phosphorus removal updgrade is neces	
EAST TROY WASTEWATER TREATMENT FACILITY	0.05	$	2,284,000
EDGERTON WASTEWATER TREATMENT FACILITY	0.431	No phosphorus removal updgrade is neces	
EGG HARBOR WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
EPHRAIM WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
FENNIMORE WASTEWATER TREATMENT FACILITY	0.05	$	2,021,000
FENWOOD WASTEWATER TREATMENT FACILITY	1.0	$	527,000
FISH CREEK SD1 WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
FONTANA WALWORTH WATER POLLUTION CONT. COMM	0.075	$	2,824,000
FOOTVILLE WASTEWATER TREATMENT FACILITY	0.075	$	1,272,000
FOREST JUNCTION SANITARY DISTRICT	0.075	$	4,024,000
FORESTVILLE WASTEWATER TREATMENT FACILITY	1.00	$	398,000
FORT ATKINSON WASTEWATER TREATMENT FACILITY	0.465	$	586,000
FREDONIA MUNICIPAL SEWER AND WATER UTILITY	0.05	$	2,512,000
GBMSD - DE PERE	0.200	No phosphorus removal updgrade is neces	
GENOA CITY VILLAGE	0.05	$	1,141,000
GIBBSVILLE SANITARY DISTRICT	0.05	$	472,000
GRAFTON VILLAGE WATER & WASTEWATER UTILITY	0.05	$	4,581,000
GRAND CHUTE MENASHA WEST SEWERAGE COMMISSION	0.200	$	6,050,000
GRATIOT WASTEWATER TREATMENT FACILITY	0.05	$	814,000
GREEN BAY METROPOLITAN SEWERAGE DISTRICT	0.200	$	23,329,000
HARTFORD WATER POLLUTION CONTROL FACILITY	0.075	$	2,834,000
HAZEL GREEN WASTEWATER TREATMENT FACILITY	0.05	$	1,353,000
HEART OF VALLEY MSD WW TRTMNT FAC	0.200	$	5,821,000
HEWITT SANITARY DISTRICT WWTP	0.05	$	1,076,000
HILBERT WASTEWATER TREATMENT FACILITY	0.05	$	1,234,000
HOLLAND SD 1 WASTEWATER TREATMENT FACILITY	0.075	$	2,196,000
HOLLANDALE WASTEWATER TREATMENT FACILITY	0.075	$	3,212,000
HOWARDS GROVE WASTEWATER TRTMT FAC	0.05	$	660,000
HUDSON WASTEWATER TREATMENT FACILITY	0.6	No phosphorus removal updgrade is neces	
JACKSON (VILLAGE) WASTEWATER TREATMENT PLANT	0.05	$	1,977,000
JAMESTOWN SANITARY DISTRICT NO 2 WWTF	0.05	$	721,000
JAMESTOWN SANITARY DISTRICT NO 3 WWTF	1.00	$	573,000
JANESVILLE WASTEWATER UTILITY	0.107	$	17,045,000
JEFFERSON WASTEWATER TREATMENT FACILITY	0.10	$	4,588,000
JUNCTION CITY WASTEWATER TREATMENT FACILITY	0.05	$	1,131,000
KENOSHA WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
KEWASKUM VILLAGE	0.05	$	2,120,000
KEWAUNEE WASTEWATER TREATMENT FACILITY	0.05	$	1,853,000
KIEL WASTEWATER TREATMENT FACILITY	0.05	$	4,630,000
KIELER SANITARY DISTRICT NO 1 WWTF	0.05	$	1,075,000
KOSSUTH SANITARY DISTRICT NO. 2 WWTF	0.05	$	727,000
LAKE TOMAHAWK TOWNSHIP SANITARY DISTRICT 1	0.05	$	800,000
LAKELAND SANITARY DISTRICT	0.05	$	1,576,000

LANCASTER WASTEWATER TREATMENT FACILITY	0.05	$ 2,093,000
LINDEN WASTEWATER TREATMENT FACILITY	0.05	$ 855,000
LIVINGSTON WASTEWATER TREATMENT FACILITY	0.05	$ 1,509,000
LYONS SANITARY DISTRICT NO 2	0.05	$ 1,623,000
MADISON METROPOLITAN SEWERAGE DISTRICT WWTF	0.075	$ 68,607,000
MANITOWOC WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces
MARATHON WATER & SEWER DPT WW TREATMNT PLANT	0.05	$ 1,289,000
MARIBEL WASTEWATER TREATMENT FACILITY	0.05	$ 1,248,000
MARSHFIELD WASTEWATER TREATMENT FACILITY	0.05	$ 6,342,000
MAUSTON WASTEWATER TREATMENT FACILITY	1.0	No phosphorus removal updgrade is neces
MEDFORD CITY OF	0.10	$ 1,758,000
MENOMONIE WASTEWATER TREATMENT FACILITY	0.10	$ 9,055,000
MERRILL CITY OF	0.05	$ 5,003,000
MILAN S D WASTEWATER TREATMENT FACILITY	1.0	$ 526,000
MILLADORE WASTEWATER TREATMENT FACILITY	0.05	$ 1,320,000
MILTON WASTEWATER TREATMENT FACILITY	0.431	$ 958,000
MILWAUKEE METRO SEW DIST: JONES ISLAND	0.05	$ 161,117,000
MILWAUKEE METRO SEW DIST: SOUTH SHORE	0.05	No phosphorus removal updgrade is neces
MINERAL POINT WASTEWATER TREATMENT FACILITY	0.05	$ 1,661,000
MONROE WASTEWATER TREATMENT FACILITY	0.05	$ 2,762,000
MORRISON SANITARY DISTRICT NO 1	0.05	$ 895,000
MOSINEE WASTEWATER TREATMENT FACILITY	0.05	$ 4,772,000
MOUNT CALVARY WASTEWATER TREATMENT FACILITY	0.05	$ 1,194,000
MOUNT HOPE WASTEWATER TREATMENT FACILITY	0.05	$ 966,000
MOUNT HOREB WASTEWATER TREATMENT FACILITY	0.10	$ 1,066,000
MUKWONAGO WASTEWATER TREATMENT PLANT	0.05	$ 3,639,000
NEENAH MENASHA SEWER COMMISSION WWTF	0.200	$ 8,155,000
NEKOOSA WASTEWATER TREATMENT FACILITY	0.05	$ 1,058,000
NEW HOLSTEIN WASTEWATER TREATMENT FACILITY	0.05	$ 2,750,000
NEW RICHMOND WASTEWATER TREATMENT FACILITY	0.6	No phosphorus removal updgrade is neces
NEWBURG VILLAGE	0.05	$ 1,165,000
NORWAY TN SANITARY DISTRICT 1 WWTF	0.05	$ 4,553,000
O DELL BAY SANITARY DISTRICT 1	1.0	$ 499,000
ONION RIVER WASTEWATER COMMISSION	0.05	$ 1,161,000
OOSTBURG WASTEWATER TREATMENT PLANT	0.05	$ 1,100,000
ORCHARD MANOR WASTEWATER TREATMENT FACILITY	0.05	$ 883,000
OREGON WASTEWATER TREATMENT FACILITY	0.075	$ 3,049,000
PADDOCK LAKE WASTEWATER TRTMNT FAC	0.05	$ 2,436,000
PALMYRA WASTEWATER TREATMENT FACILITY	0.228	$ 904,000
PATCH GROVE WASTEWATER TREATMENT FACILITY	0.05	$ 918,000
PELL LAKE SANITARY DISTRICT NO. 1	0.05	$ 1,539,000
PEPIN WASTEWATER TREATMENT FACILITY	0.1	$ 1,274,000
PHELPS SANITARY DISTRICT #1	1.0	$ 522,000
PITTSVILLE WATER AND SEWER DEPT WWTF	1.0	$ 545,000
PLATTEVILLE WASTEWATER TREATMENT FACILITY	0.05	$ 4,237,000
PLOVER WASTEWATER TREATMENT FACILITY	0.05	$ 2,907,000
PLYMOUTH CITY UTIL COMMISSION WWTF	0.05	$ 2,109,000
PLYMOUTH TOWN SANITARY DISTRICT #1 WWTF	0.075	$ 3,134,000
PORT EDWARDS WASTEWATER TREATMENT FACILITY	0.05	$ 1,825,000
PORT WASHINGTON WWTP	0.50	No phosphorus removal updgrade is neces
POTOSI-TENNYSON SEWAGE COMMISSION WWTF	0.05	$ 1,611,000
POTTER WASTEWATER TREATMENT FACILITY	0.05	$ 813,000
RACINE WASTEWATER UTILITY	0.50	No phosphorus removal updgrade is neces
RANDOM LAKE VILLAGE	0.05	$ 727,000
REEDSVILLE WASTEWATER TREATMENT FACILITY	0.05	$ 1,612,000

REWEY WASTEWATER TREATMENT FACILITY	0.05	$	787,000
RHINELANDER CITY OF	0.05	$	4,734,000
RIB LAKE VILLAGE OF	0.05	$	1,222,000
RIB MOUNTAIN METRO SEWAGE DISTRICT WWTF	0.05	$	13,815,000
RIDGEWAY WASTEWATER TREATMENT FACILITY	0.05	$	964,000
ROCKDALE WASTEWATER TREATMENT FACILITY	0.075	$	720,000
ROCKLAND SD1 WASTEWATER TREATMENT FACILITY	0.05	$	466,000
RUDOLPH WASTEWATER TREATMENT FACILITY	1.0	$	508,000
RUSSELL SANITARY DISTRICT #1 TOWN OF	0.05	$	936,000
SALEM UTILITY DISTRICT	0.05	$	4,358,000
SAUKVILLE VILLAGE SEWER UTILITY	0.05	$	2,769,000
SEVASTOPOL SD NO 1 WWTF	0.05	$	513,000
SHARON WASTEWATER TREATMENT FACILITY	0.075	$	992,000
SHEBOYGAN WASTEWATER TREATMENT PLANT	0.50	No phosphorus removal updgrade is neces	
SHERWOOD WASTEWATER TREATMENT FACILITY	0.05	$	1,068,000
SHULLSBURG WASTEWATER TREATMENT FACILITY	0.05	$	1,690,000
SILVER LAKE SANITARY DISTRICT	0.1	$	1,331,000
SILVER LAKE VILLAGE	0.05	$	2,095,000
SISTER BAY WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
SOUTH MILWAUKEE WASTEWATER TREAT FACILITY	0.50	No phosphorus removal updgrade is neces	
SOUTH WAYNE WASTEWATER TREATMENT FACILITY	0.05	$	964,000
SPENCER WASTEWATER TREATMENT FACILITY	0.05	$	1,438,000
ST CLOUD VILLAGE UTILITY COMMISSION	1.0	$	476,000
ST NAZIANZ WASTEWATER TREATMENT FACILITY	0.05	$	924,000
STETSONVILLE, VILLAGE OF	0.05	$	1,112,000
STEVENS POINT WASTEWATER TREATMENT FACILITY	0.05	$	6,572,000
STITZER SANITARY DISTRICT WWTF	0.05	$	827,000
STOUGHTON WASTEWATER TREATMENT FACILITY	0.075	$	4,977,000
STRATFORD WASTEWATER TREATMENT FACILITY	0.05	$	2,517,000
STURGEON BAY UTILITIES WWTF	0.50	No phosphorus removal updgrade is neces	
SULLIVAN TWN SANITARY DISTRICT #1 WWTF	0.660	$	380,000
SULLIVAN WASTEWATER TREATMENT FACILITY	0.075	$	932,000
SUN PRAIRIE WASTEWATER TREATMENT FACILITY	0.075	$	3,991,000
SUSSEX WASTEWATER TREATMENT FACILITY	0.05	$	3,086,000
THREE LAKES SANITARY DISTRICT #1	0.05	$	880,000
TOMAHAWK CITY OF	0.05	$	1,431,000
TWIN LAKES WASTEWATER TREATMENT FAC	0.05	$	3,826,000
TWO RIVERS WASTEWATER TREATMENT FACILITY	0.50	No phosphorus removal updgrade is neces	
UNION GROVE VILLAGE	0.05	$	3,807,000
UNITY WASTEWATER TREATMENT FACILITY	1.0	$	469,000
VALDERS WASTEWATER TREATMENT FACILITY	0.05	$	1,382,000
VESPER WASTEWATER TREATMENT FACILITY	1.0	$	512,000
WALDO WASTEWATER UTILITY	0.05	$	1,279,000
WALWORTH COUNTY METRO	0.075	$	5,072,000
WARRENS	0.50	$	305,000
WATERLOO WASTEWATER TREATMENT FACILITY	0.075	$	790,000
WATERTOWN WASTEWATER TREATMENT FACILITY	0.10	$	4,931,000
WAUKESHA CITY	0.05	$	6,974,000
WAUPUN WASTEWATER TREATMENT FACILITY	0.05	$	4,592,000
WAUSAU WATER WORKS WW TREATMENT FACILITY	0.05	$	5,427,000
WEST BEND CITY	0.05	$	7,235,000
WESTERN RACINE COUNTY SEWERAGE DISTRICT	0.05	$	6,400,000
WHITELAW WASTEWATER TREATMENT FACILITY	0.05	$	1,115,000
WHITEWATER WASTEWATER TREATMENT FACIL	0.204	$	465,000
WHITING WASTEWATER TREATMENT FACILITY	0.05	$	1,033,000

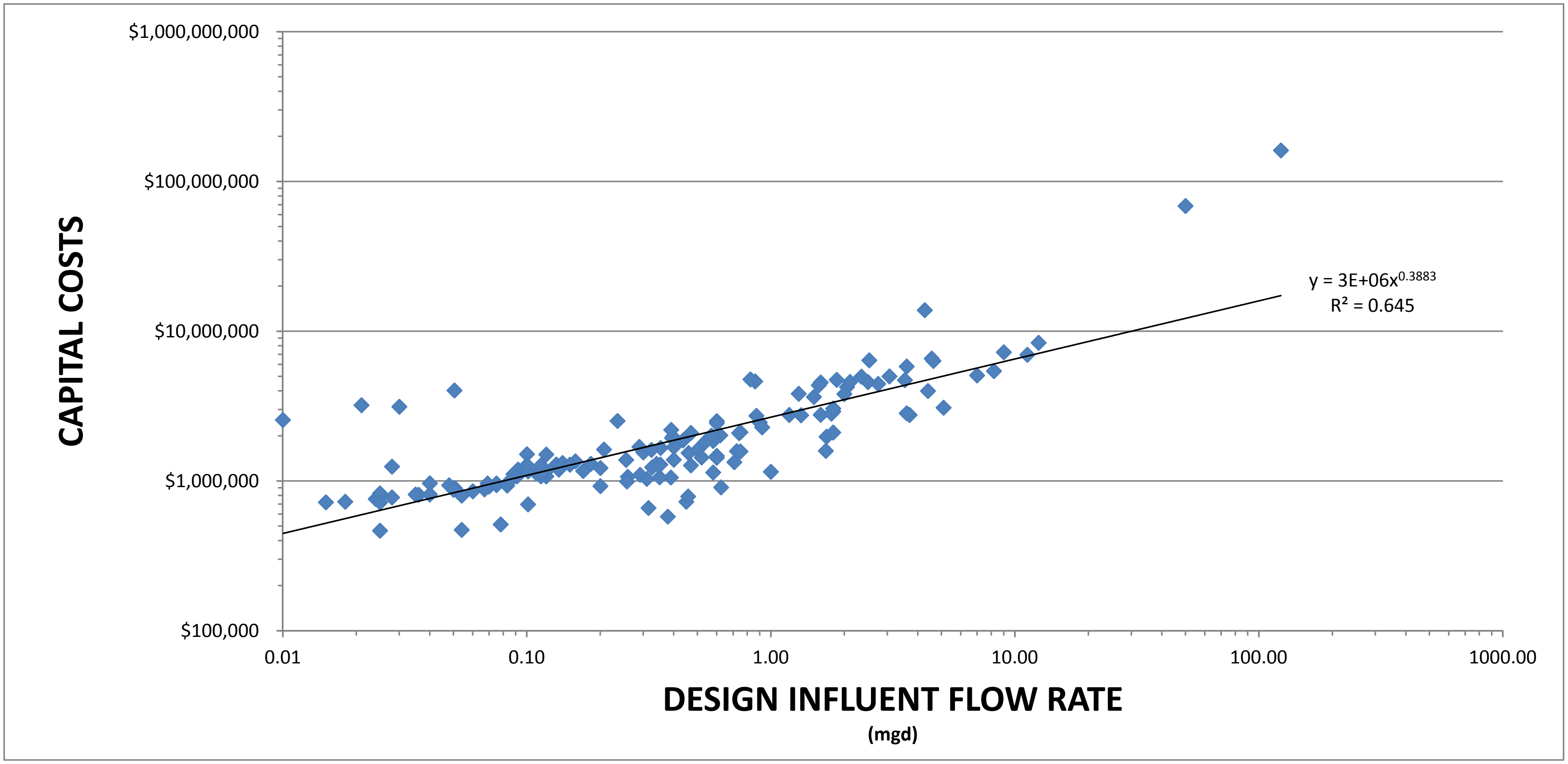
WI DELLS LK DELTON SEWERAGE COMMISSION WWTF	0.10	$	1,694,000
WI DNR PENINSULA STATE PARK WWTF	0.05	$	874,000
WI DNR RICHARD BONG RECREATION AREA	1.00	$	431,000
WI DNR YELLOWSTONE LAKE STATE PARK WWTF	0.05	No phosphorus removal updgrade is neces	
WI DOC LINCOLN HILLS SCHOOL	1.0	$	553,000
WISCONSIN RAPIDS WWTF	0.05	$	4,714,000
WRIGHTSTOWN SANITARY DISTRICT 1	0.075	$	1,003,000
WRIGHTSTOWN SANITARY DISTRICT 2	0.075	$	2,559,000
WRIGHTSTOWN SEWER & WATER UTILITY	0.382	No phosphorus removal updgrade is neces	
YORKVILLE SEWER UTILITY DISTRICT NO 1	0.05	$	1,287,000

APPENDIX B
DATA GRAPHS
<0.1 mg/l Phosphorus Effluent Group

DATA GRAPH B.1

CAPITAL COST VS. DESIGN INFLUENT FLOW RATE

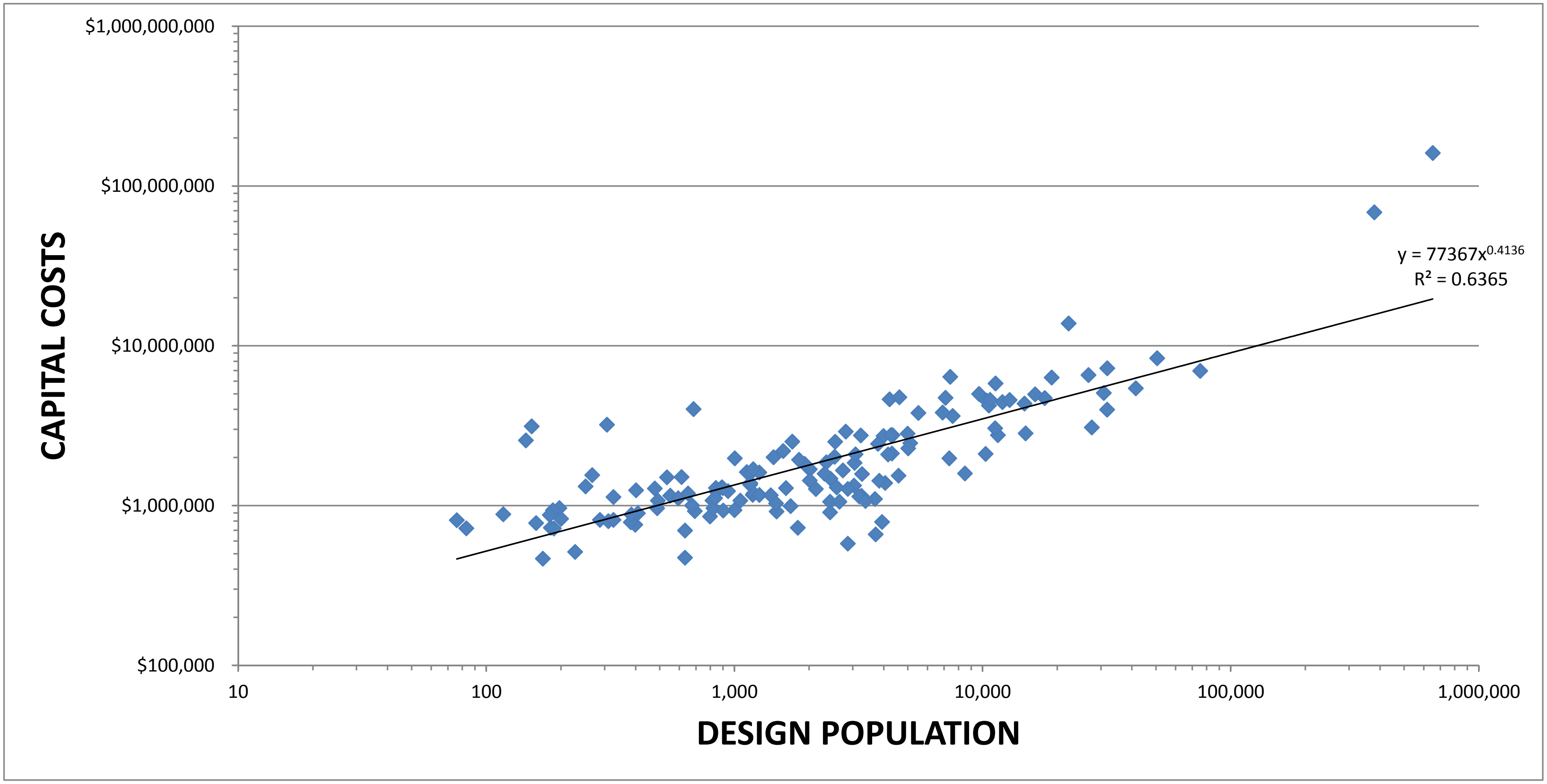
EFFLUENT GROUP: <0.1 mg/l



DATA GRAPH B.2

CAPITAL COST VS. DESIGN POPULATION

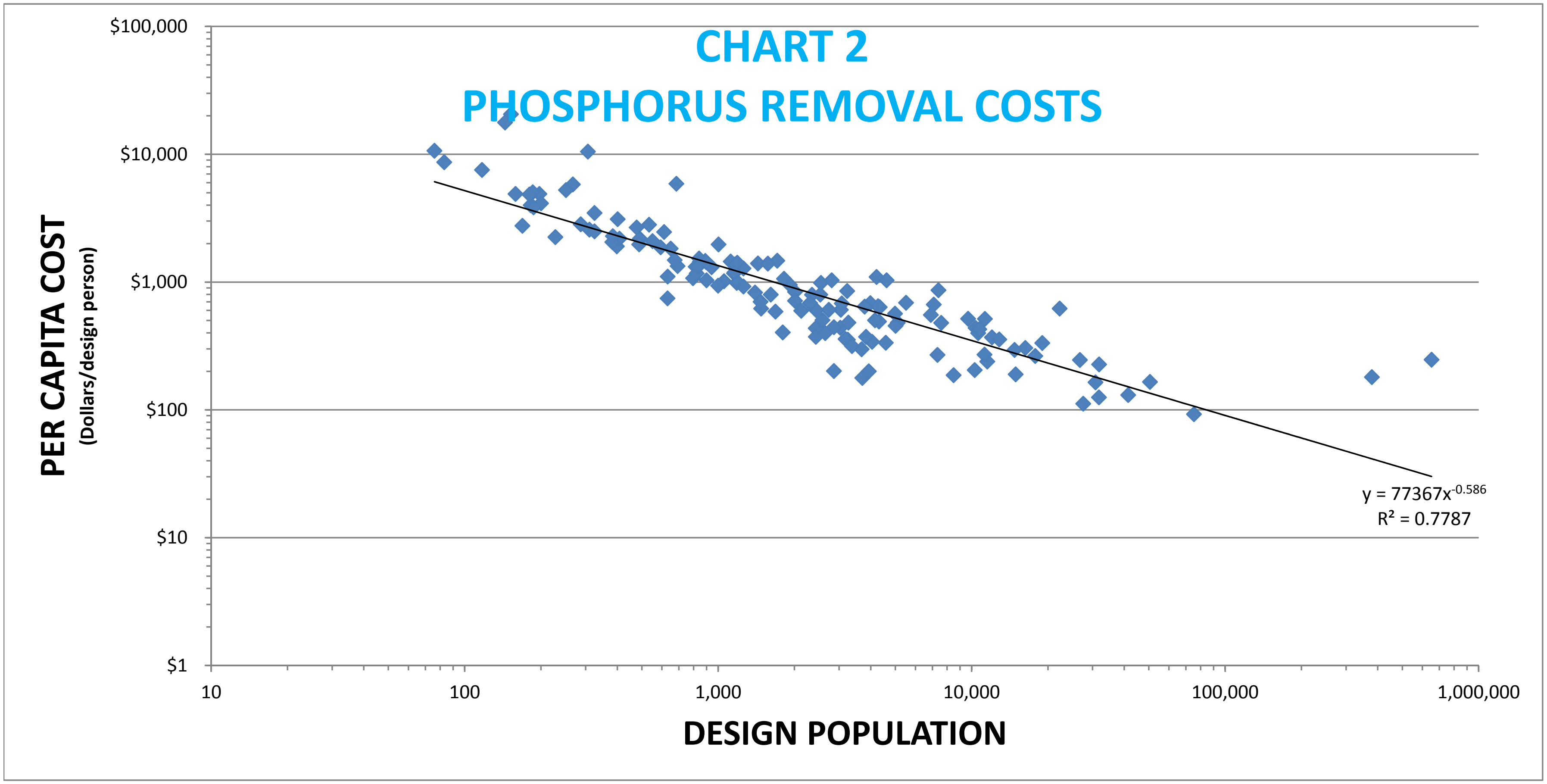
EFFLUENT GROUP: <0.1 mg/l



DATA GRAPH B.3

PER CAPITA COST VS. DESIGN POPULATION

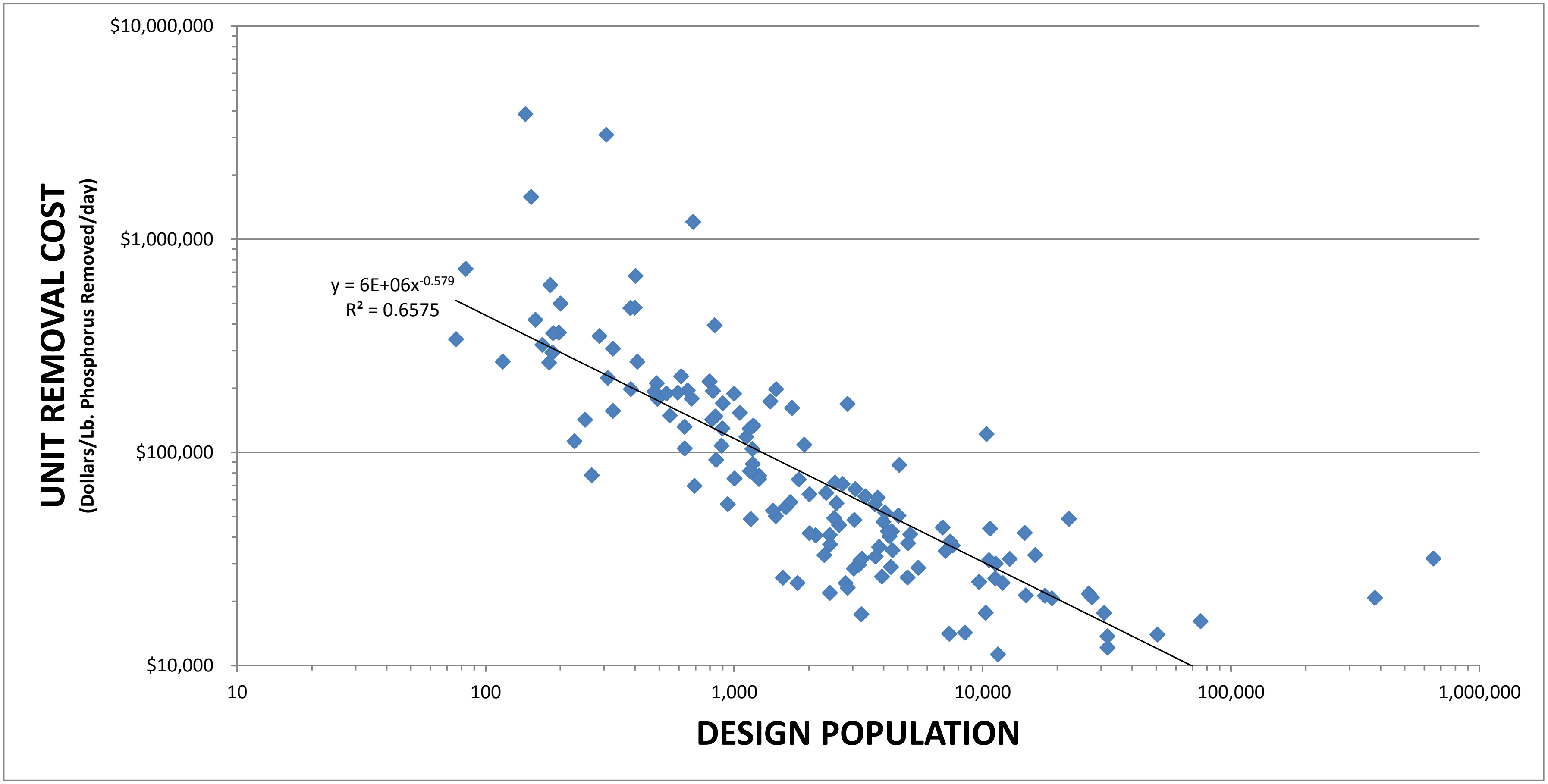
EFFLUENT GROUP: <0.1 mg/l



DATA GRAPH B.4

UNIT PHOSPHORUS REMOVAL COST VS. DESIGN POPULATION

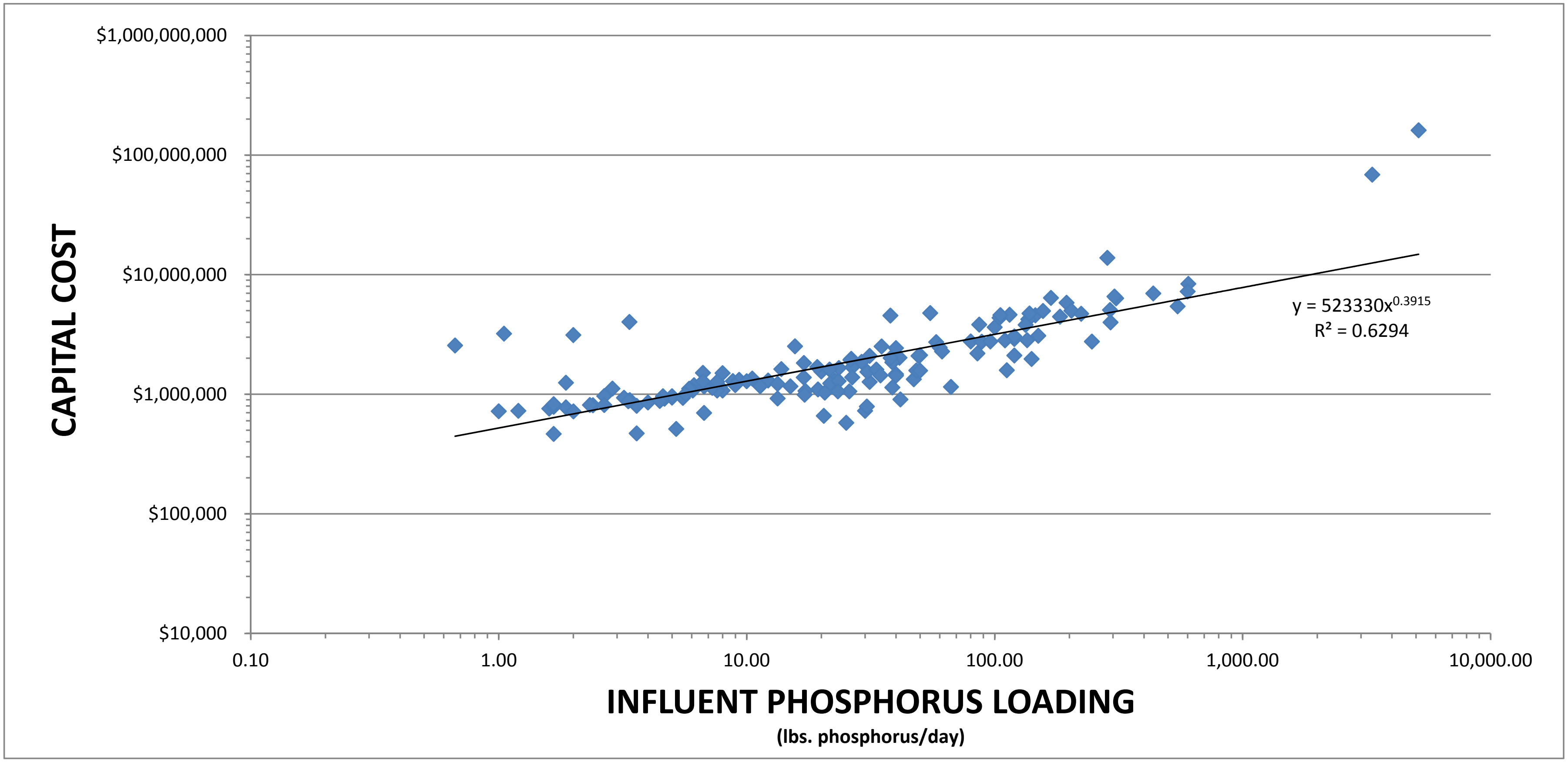
EFFLUENT GROUP: <0.1 mg/l



DATA GRAPH B.5

CAPITAL COST VS. INFLUENT PHOSPHORUS LOADING

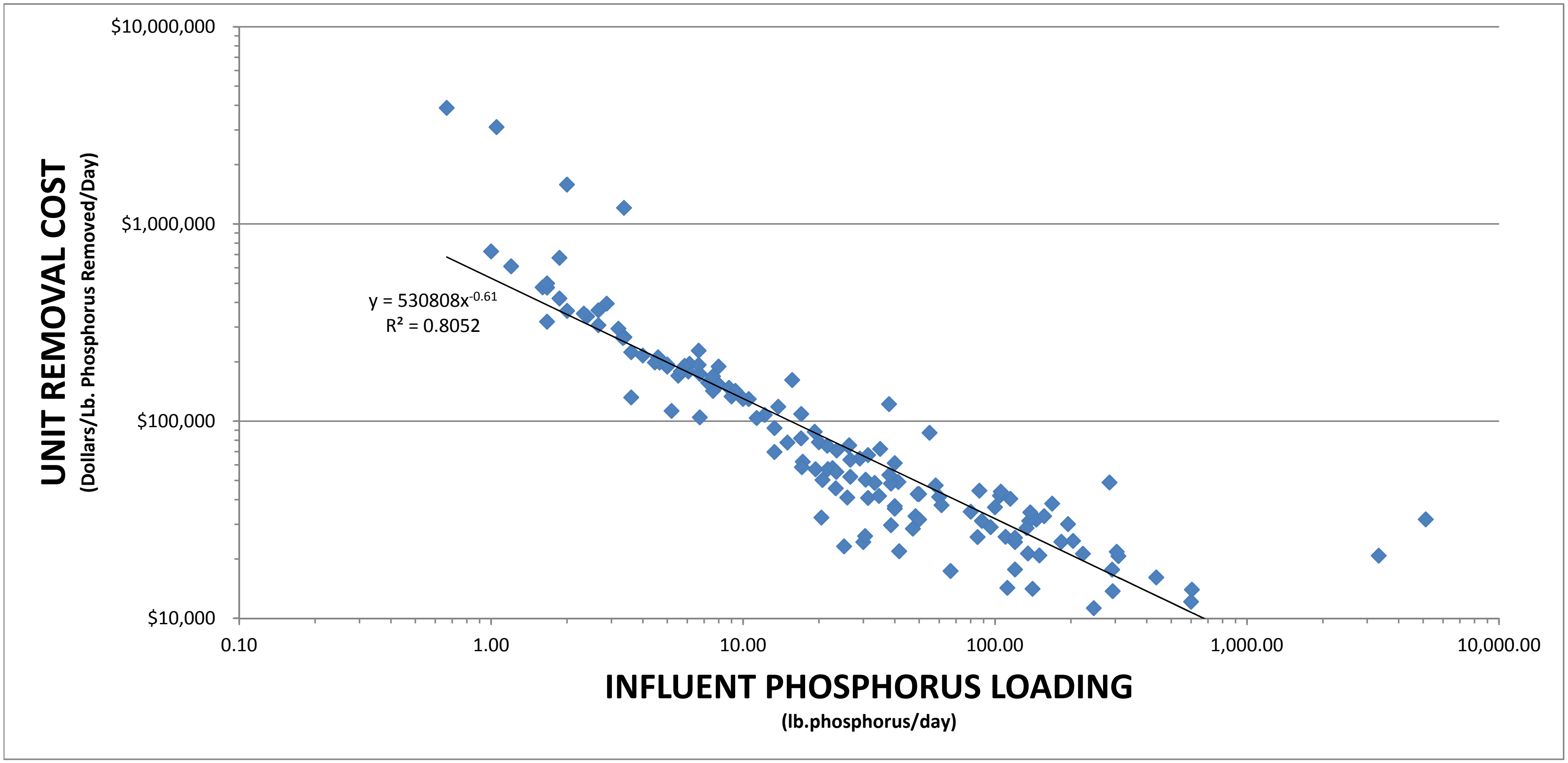
EFFLUENT GROUP: <0.1 mg/l



DATA GRAPH B.6

UNIT PHOSPHORUS REMOVAL COST VS. INFLUENT PHOSPHORUS LOADING

EFFLUENT GROUP: <0.1 mg/l

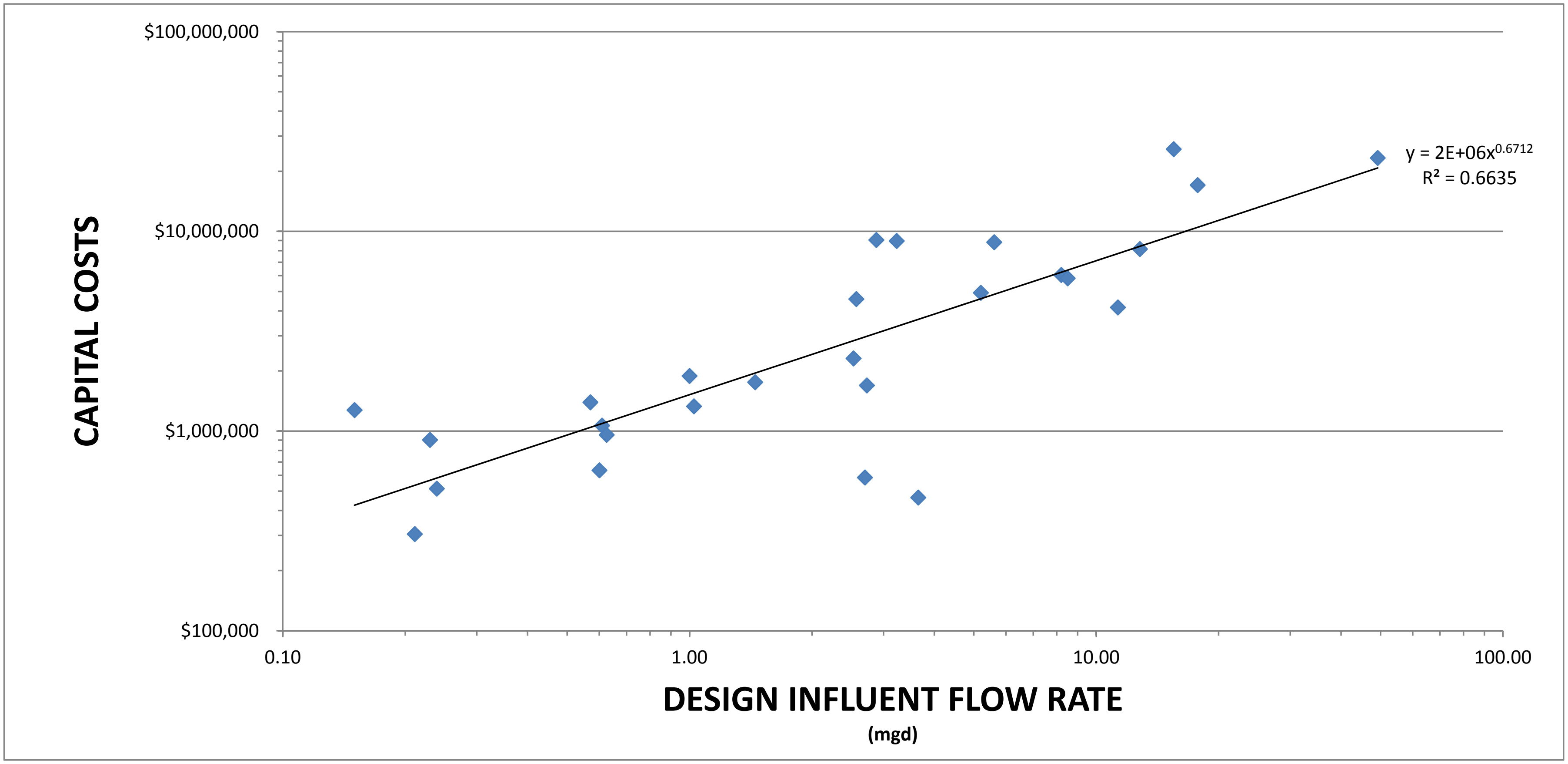


APPENDIX C
DATA GRAPHS
0.1 to <0.5 mg/l Phosphorus Effluent Group

DATA GRAPH C.1

CAPITAL COST VS. DESIGN INFLUENT FLOW RATE

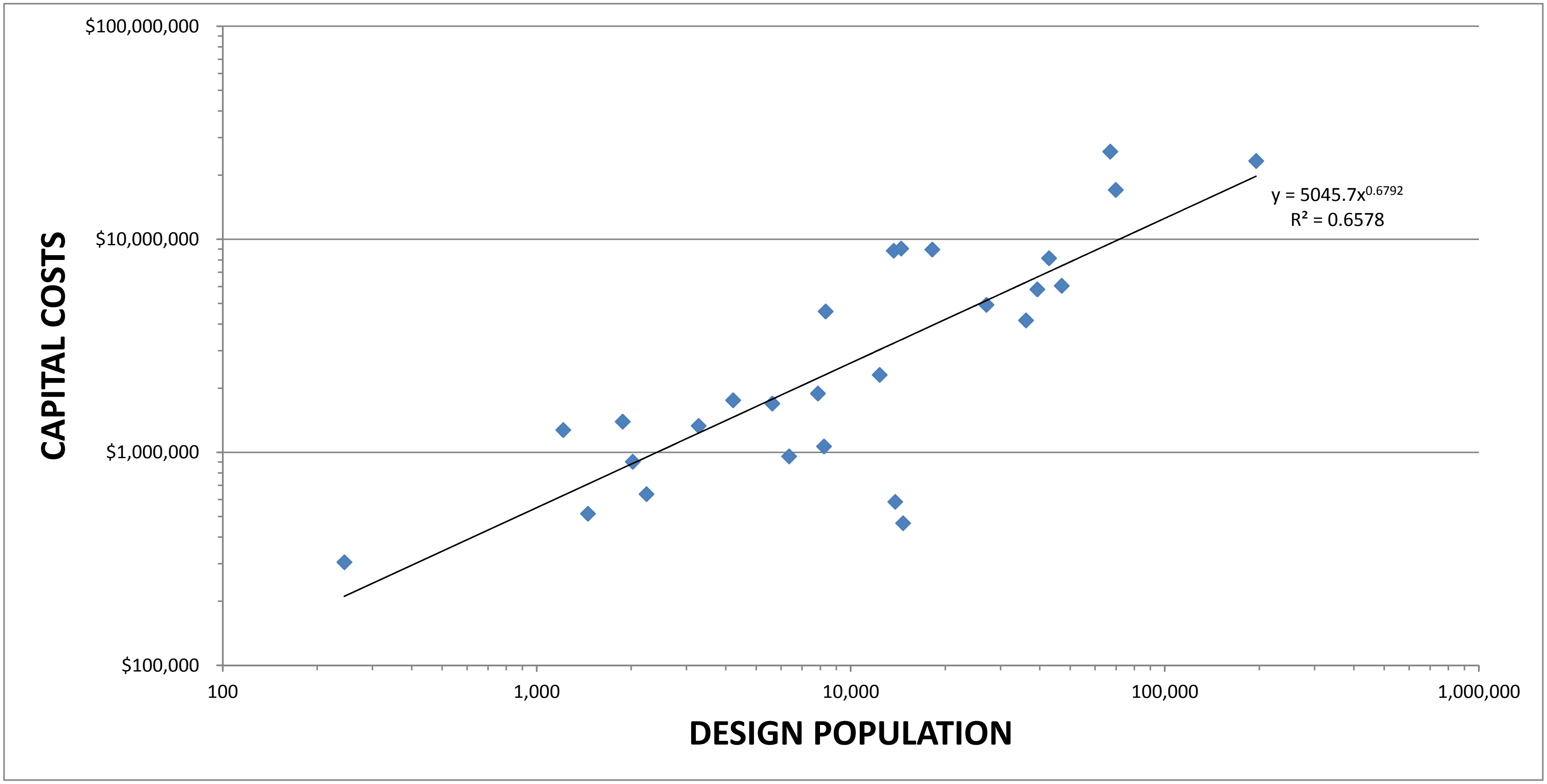
EFFLUENT GROUP: 0.1 to <0.5 mg/l



DATA GRAPH C.2

CAPITAL COST VS. DESIGN POPULATION

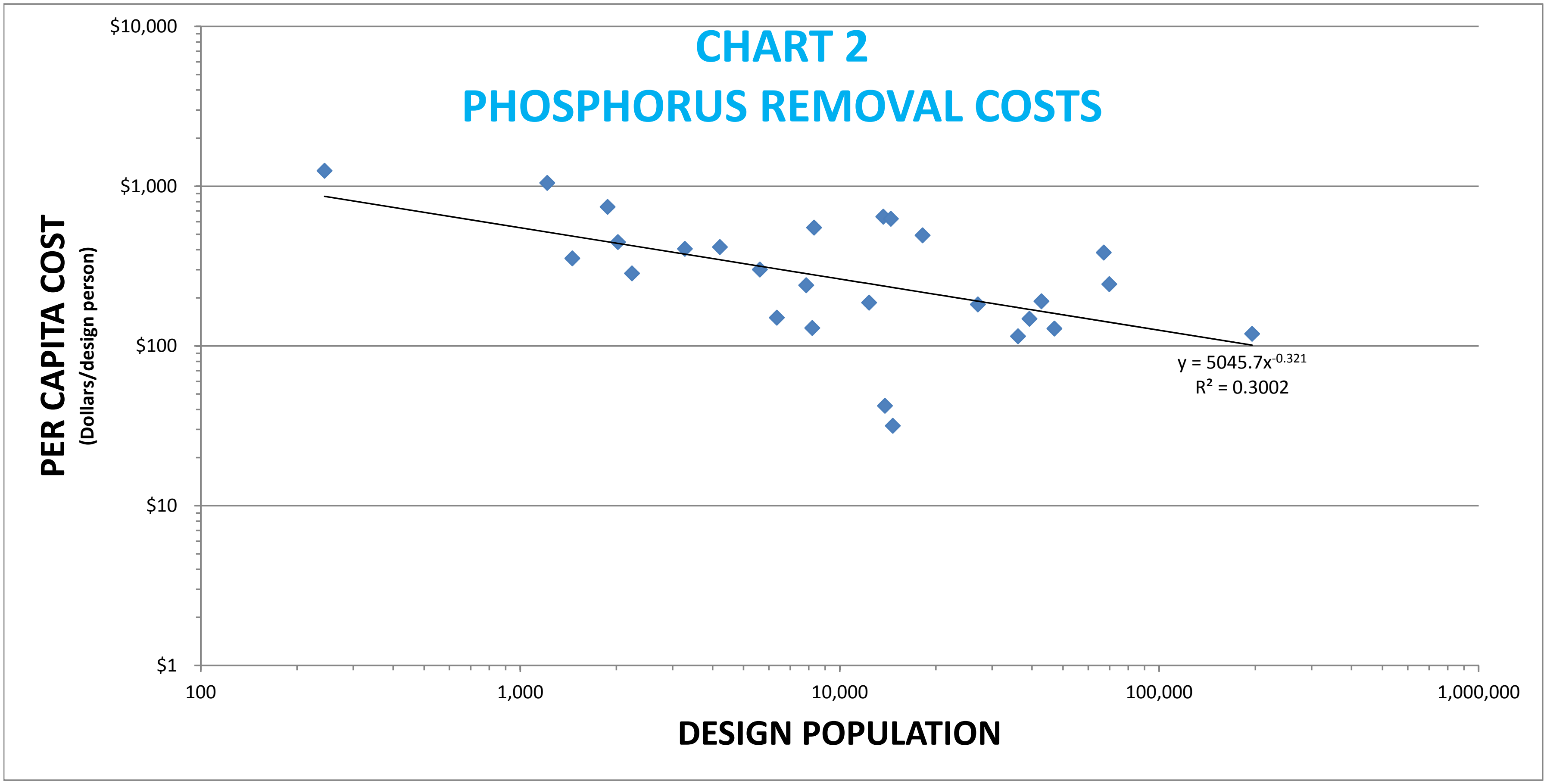
EFFLUENT GROUP: 0.1 to <0.5 mg/l



DATA GRAPH C.3

PER CAPITA COST VS. DESIGN POPULATION

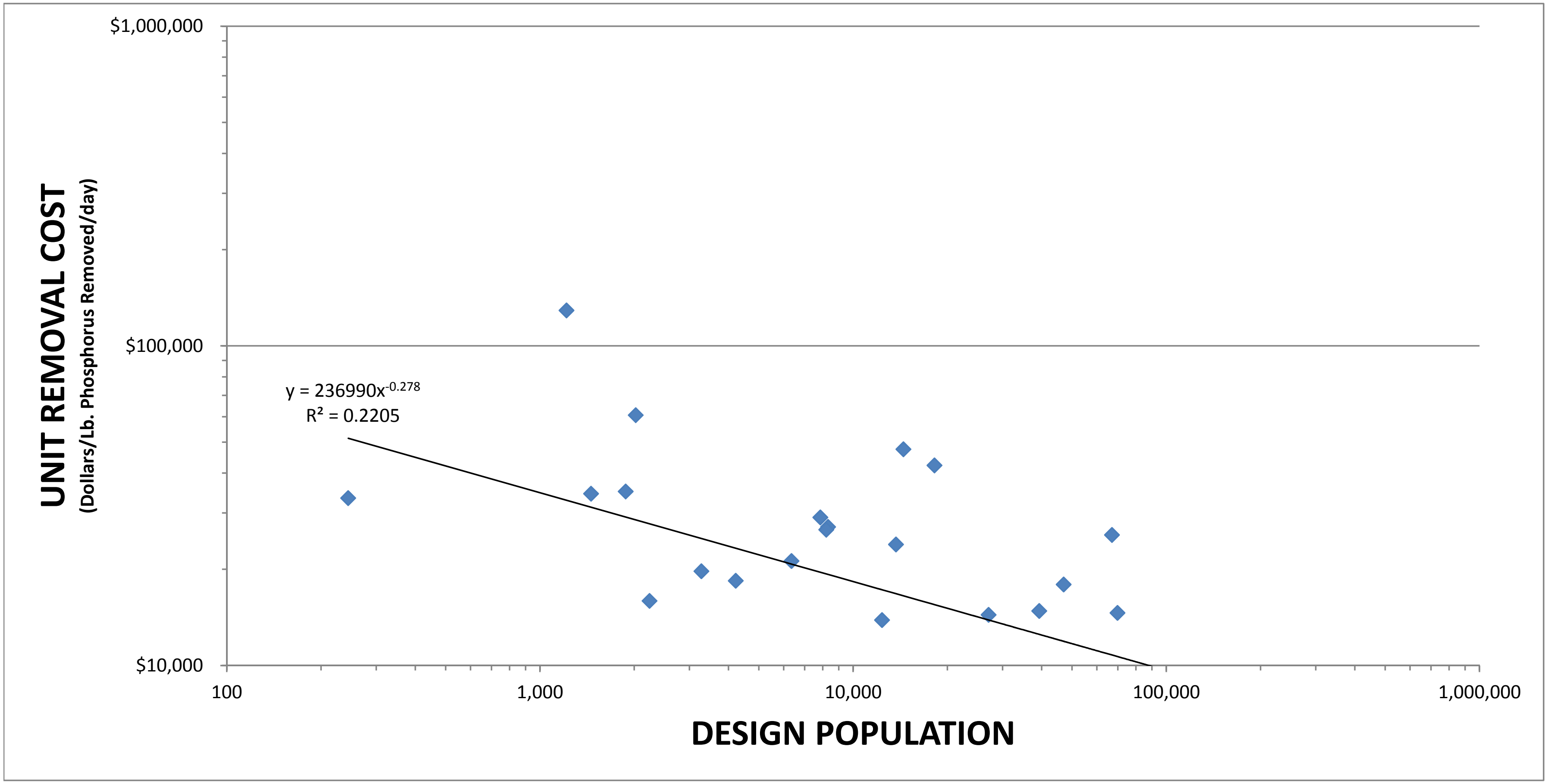
EFFLUENT GROUP: 0.1 to <0.5 mg/l



DATA GRAPH C.4

UNIT PHOSPHORUS REMOVAL COST VS. DESIGN POPULATION

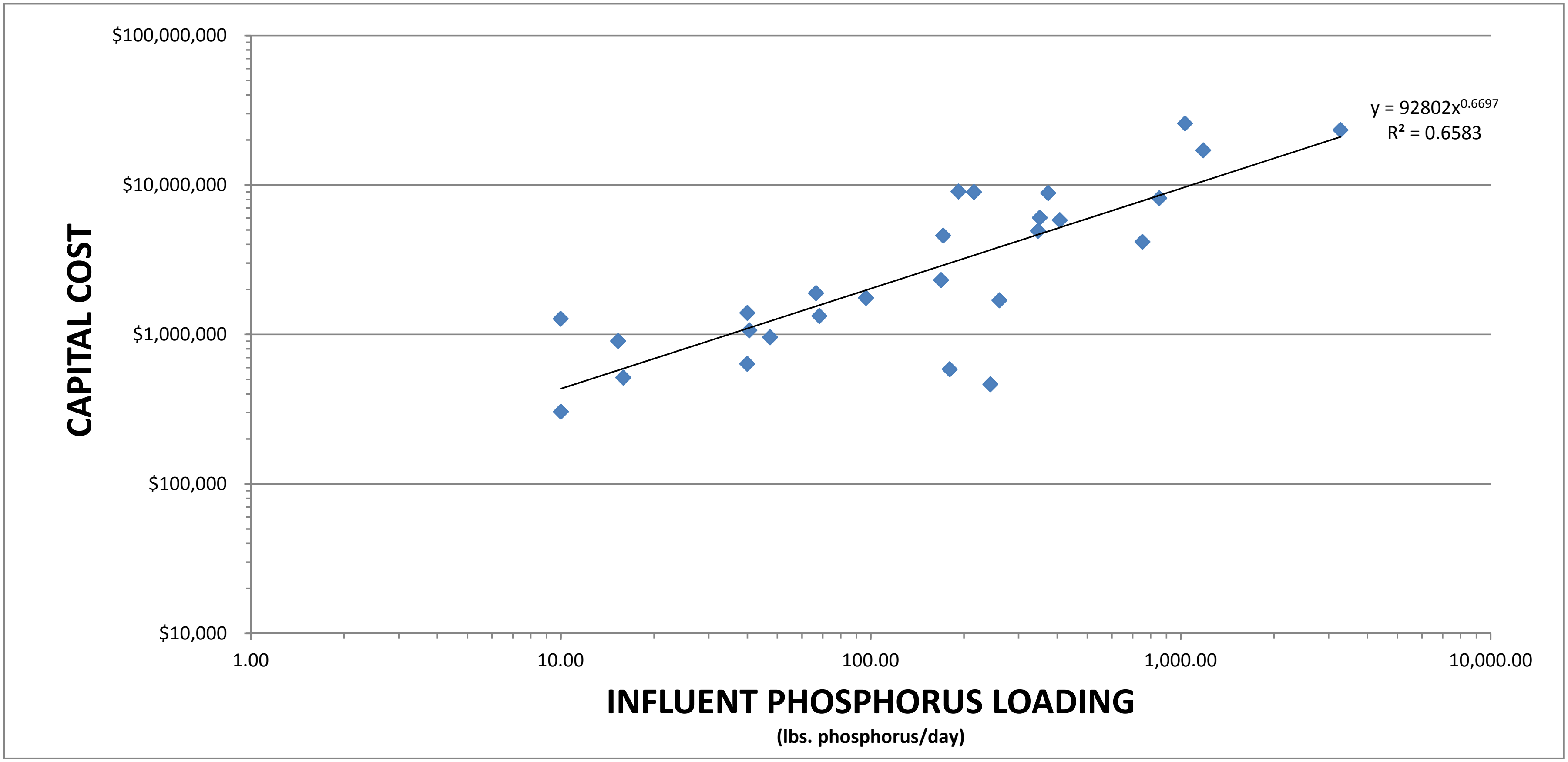
EFFLUENT GROUP: 0.1 to <0.5 mg/l



DATA GRAPH C.5

CAPITAL COST VS. INFLUENT PHOSPHORUS LOADING

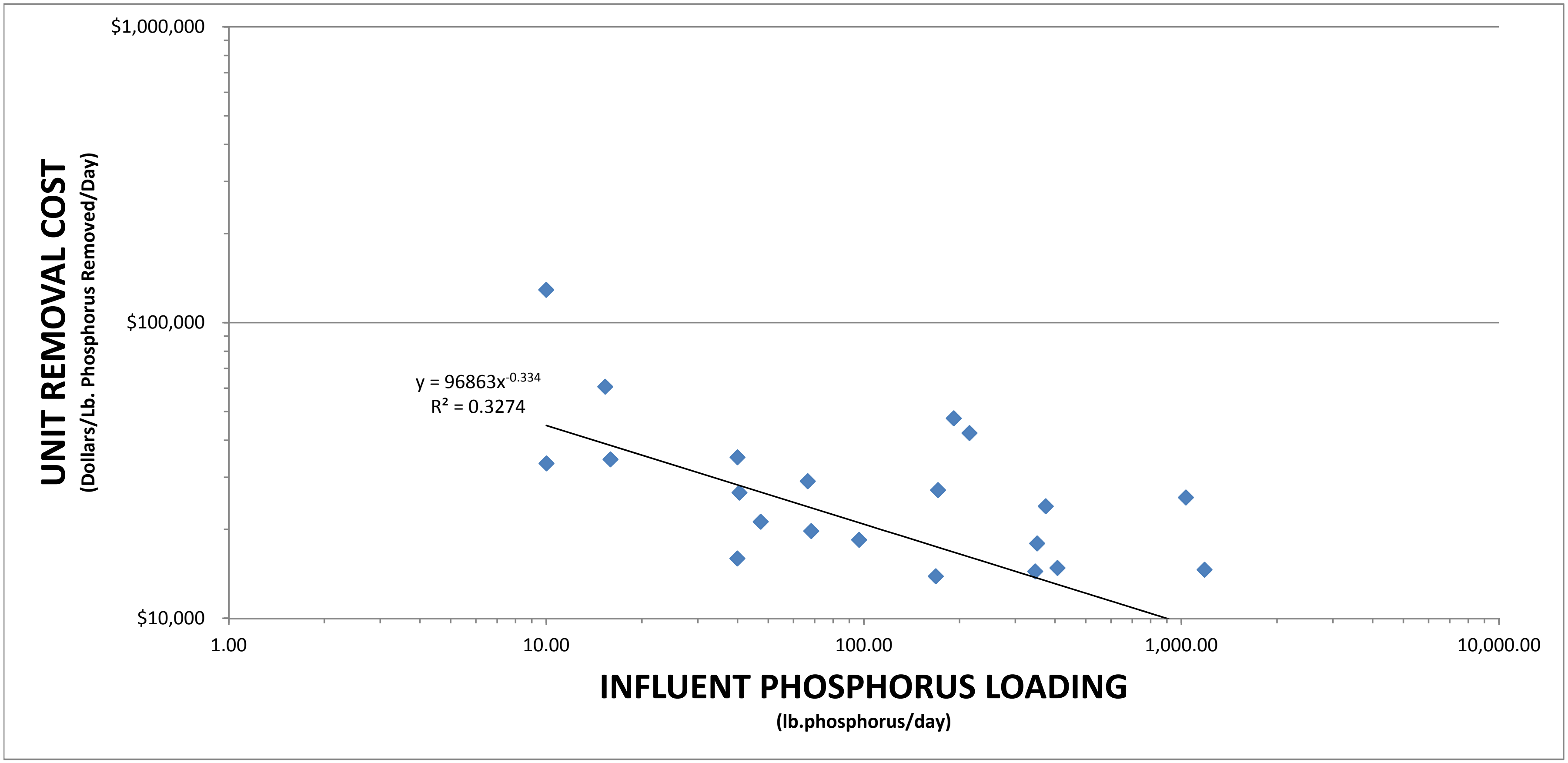
EFFLUENT GROUP: 0.1 to <0.5 mg/l



DATA GRAPH C.6

UNIT PHOSPHORUS REMOVAL COST VS. INFLUENT PHOSPHORUS LOADING

EFFLUENT GROUP: 0.1 to <0.5 mg/l

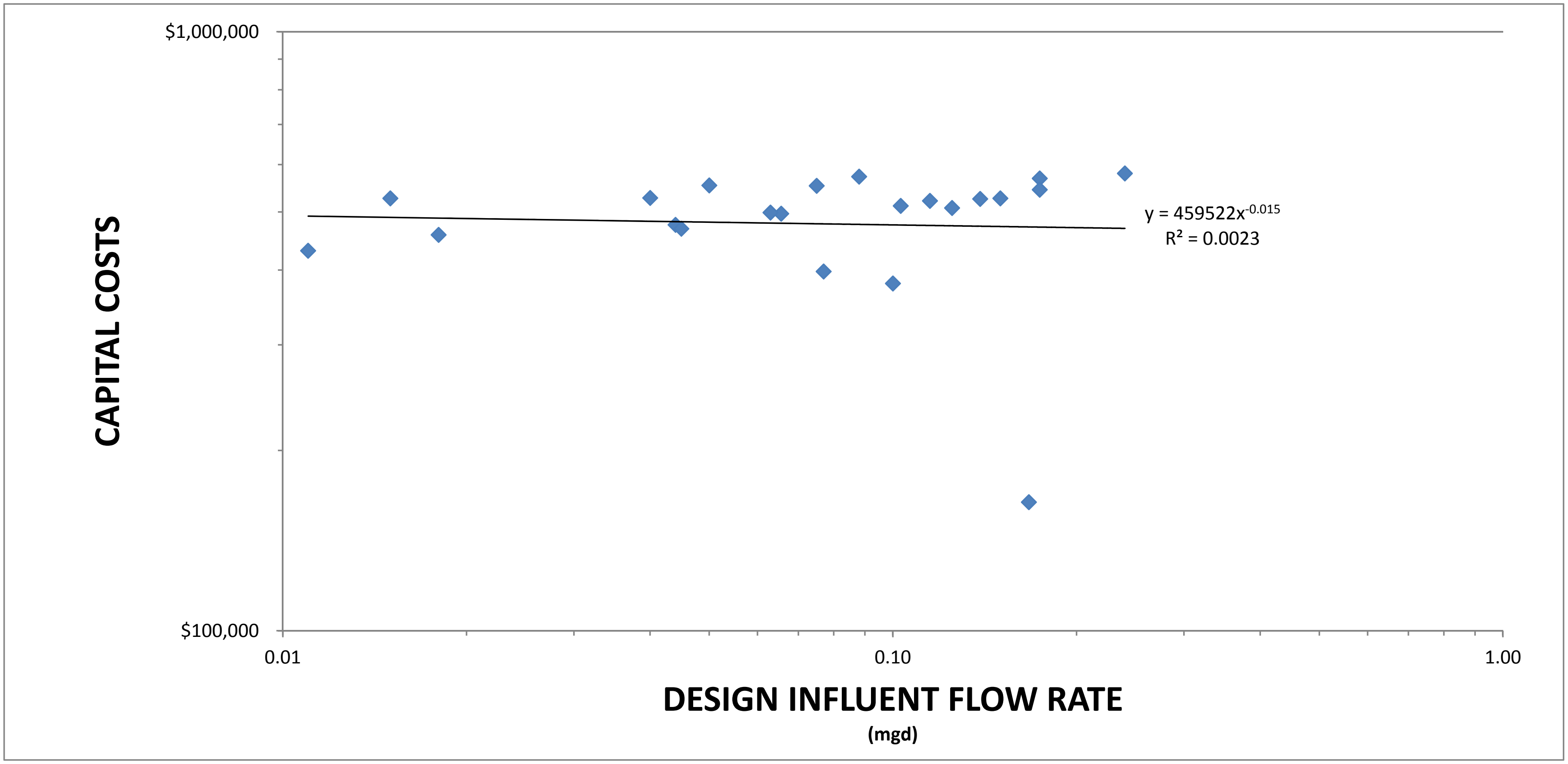


APPENDIX D
DATA GRAPHS
0.5 to <1.0 mg/l Phosphorus Effluent Group

DATA GRAPH D.1

CAPITAL COST VS. DESIGN INFLUENT FLOW RATE

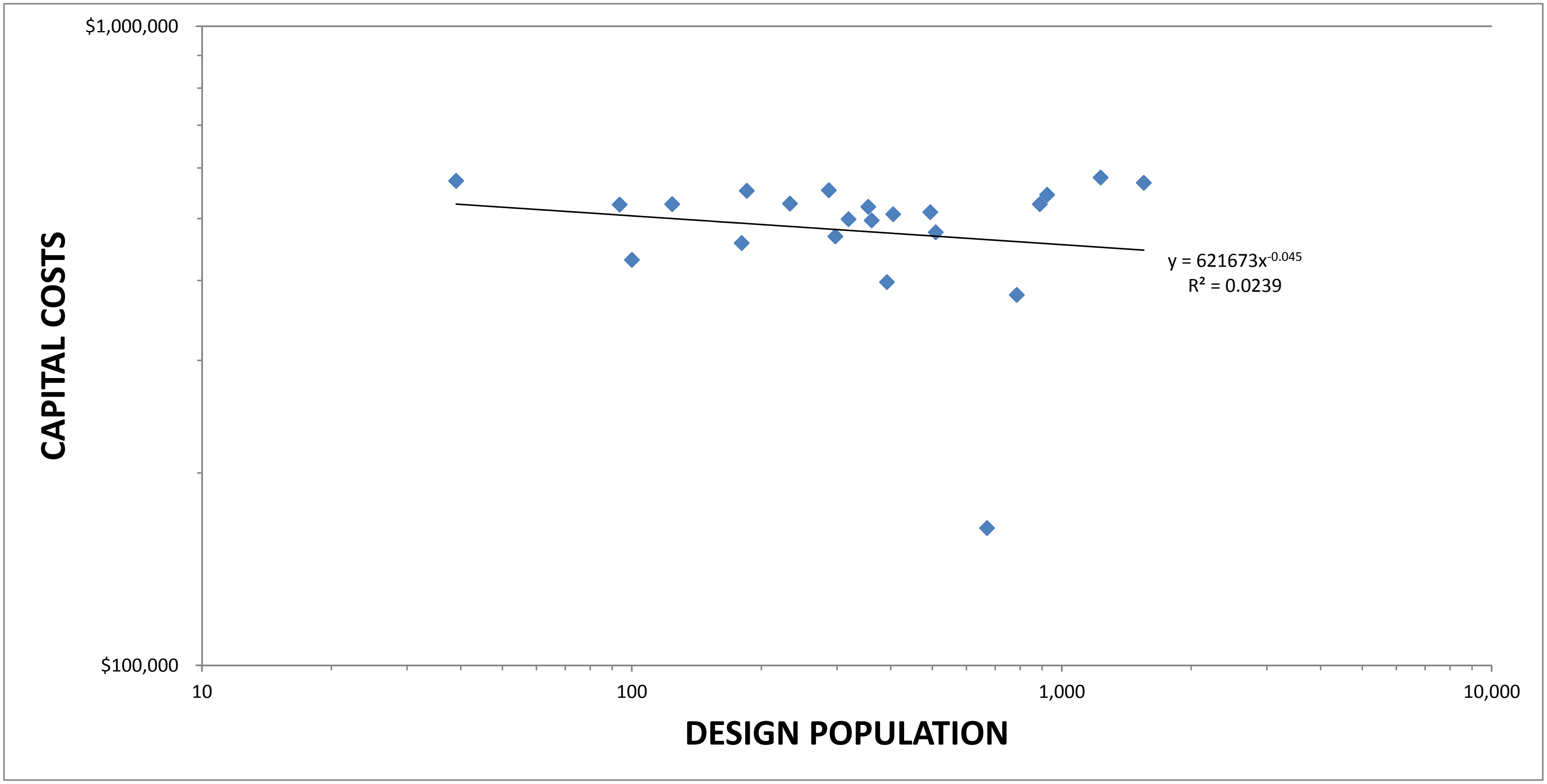
EFFLUENT GROUP: 0.5 TO <1.0 mg/l



DATA GRAPH D.2

CAPITAL COST VS. DESIGN POPULATION

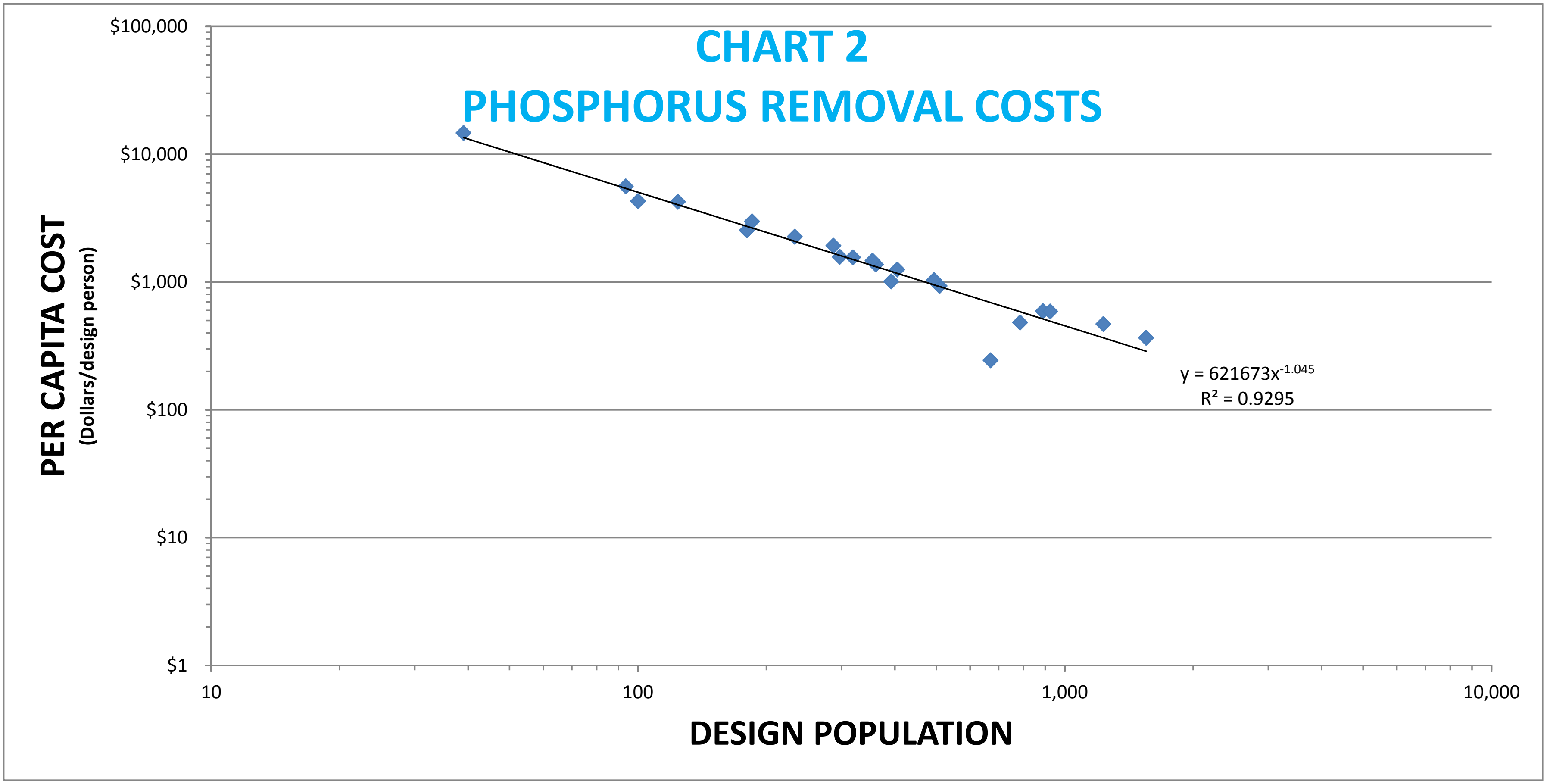
EFFLUENT GROUP: 0.5 TO <1.0 mg/l



DATA GRAPH D.3

PER CAPITA COST VS. DESIGN POPULATION

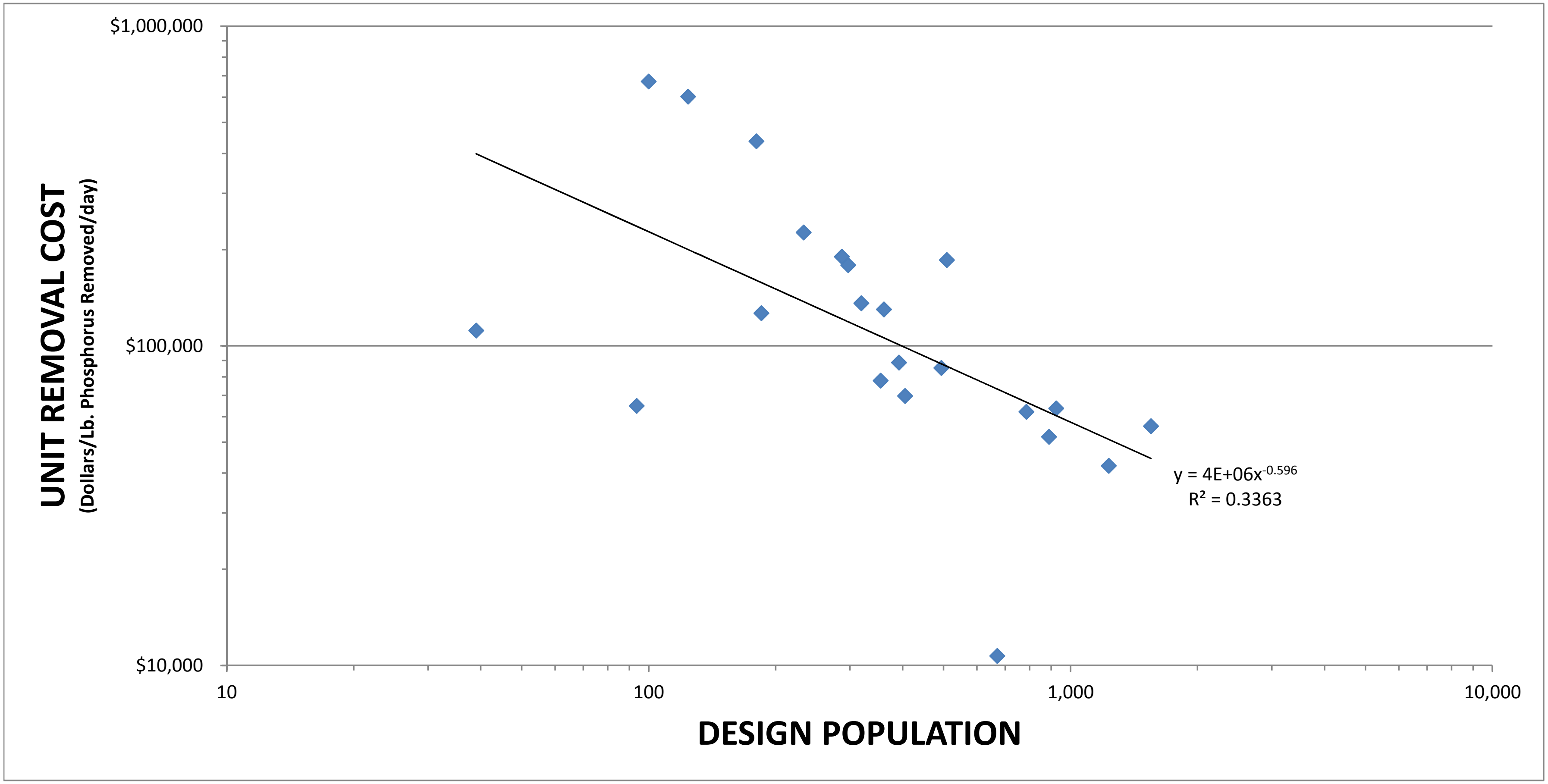
EFFLUENT GROUP: 0.5 TO <1.0 mg/l



DATA GRAPH D.4

UNIT PHOSPHORUS REMOVAL COST VS. DESIGN POPULATION

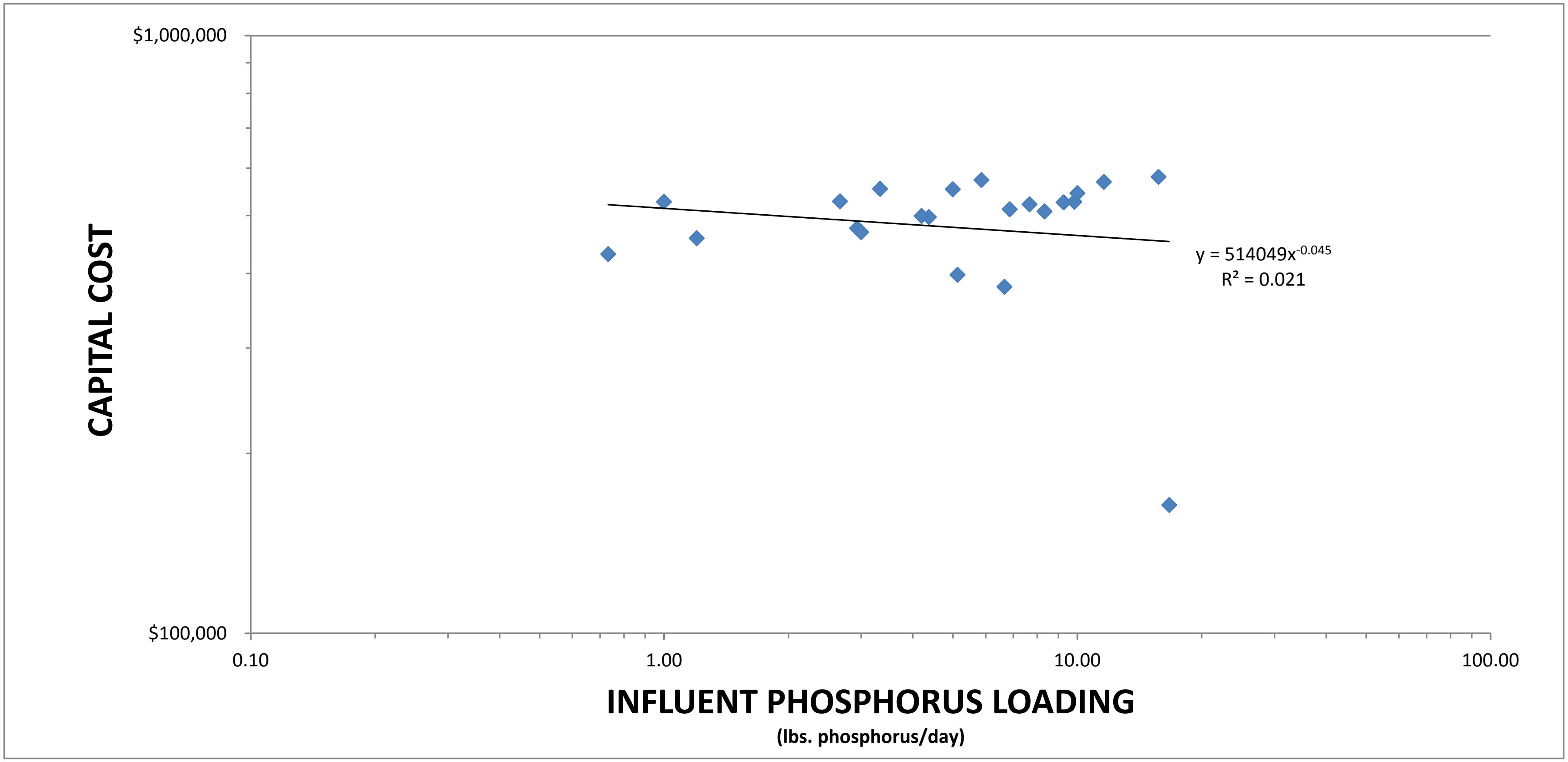
EFFLUENT GROUP: 0.5 TO <1.0 mg/l



DATA GRAPH D.5

CAPITAL COST VS. INFLUENT PHOSPHORUS LOADING

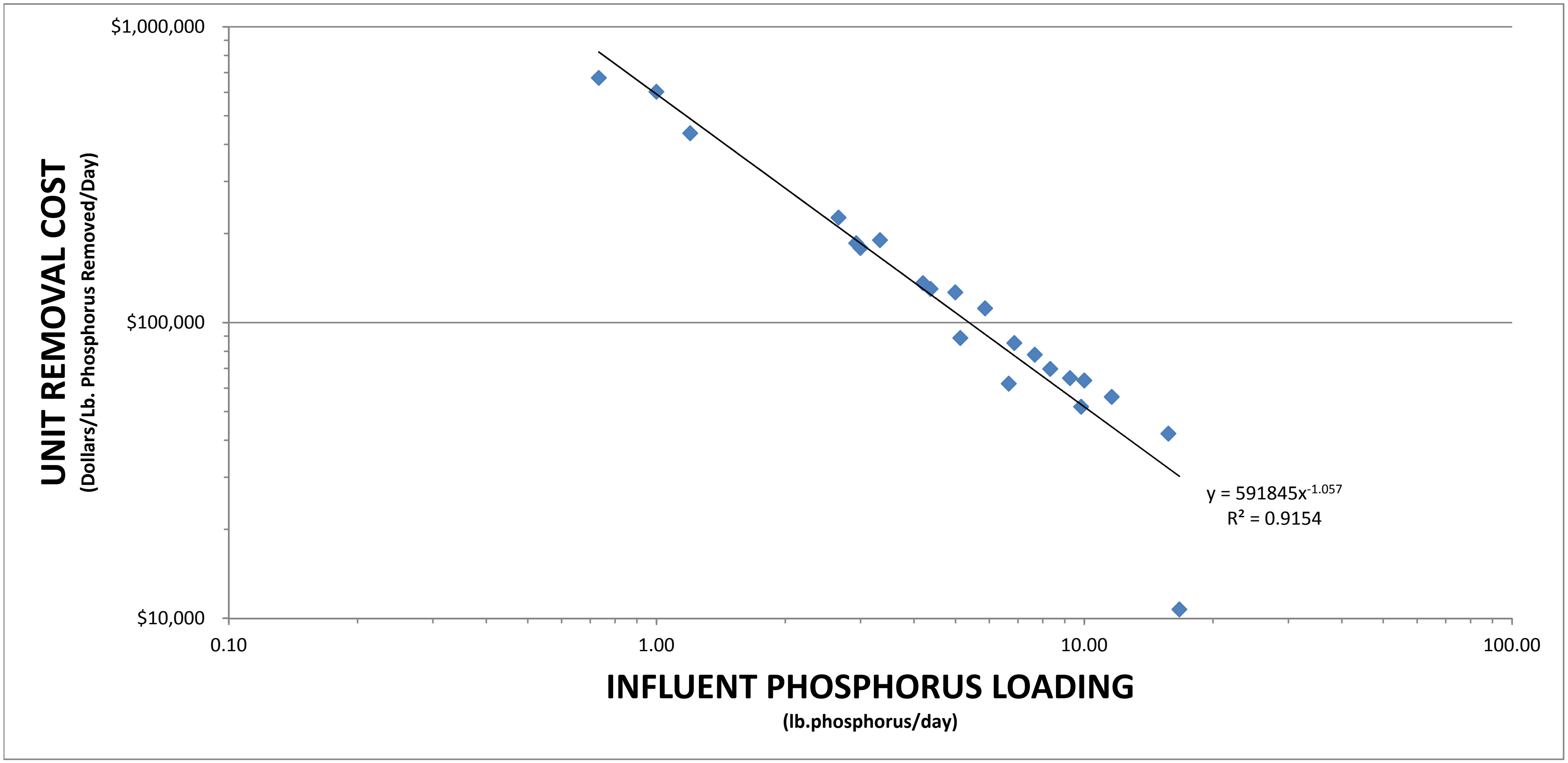
EFFLUENT GROUP: 0.5 TO <1.0 mg/l



DATA GRAPH D.6

UNIT PHOSPHORUS REMOVAL COST VS. INFLUENT PHOSPHORUS LOADING

EFFLUENT GROUP: 0.5 TO <1.0 mg/l



APPENDIX E
DATA STATISTICS

DATA STATISTICS

DATA STATISTICS	EFFLUENT GROUP		
	< 0.1 mg/l	**0.1 to < 0.5 mg/l**	**0.5 to < 1.0 mg/l**
Population			
Minimum	76	1,214	39
Maximum	562,080	195,360	1,551
Median	1,524	13,690	358
Mean	12,362	26,511	505
Design Influent Flow (mgd)			
Minimum	.010	0.150	0.011
Maximum	123.000	49.200	0.240
Median	.313	2.730	0.094
Mean	2.267	6.424	0.105
Design Phosphorus Removed (lbs/day)			
Minimum	0.66	9.87	0.64
Maximum	5,069.29	3,195.19	15.29
Median	20.09	190.63	5.57
Mean	121.49	407.76	6.28
Capital Cost			
Minimum	$466,000	$465,000	$164,000
Maximum	$161,117,000	$25,809,000	$580,000
Median	$1,311,500	$2,311,000	$513,000
Mean	$3,751,260	$5,720,200	$484,000