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TECHNOLOGIES & COSTS FOR POINT-OF-ENTRY (POE) AND POINT-OF-USE (POU) DEVICES FOR CONTROL OF DISINFECTION BY-PRODUCTS (FINAL REPORT)

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1.1 BACKGROUND

The use of disinfection to reduce waterborne disease in drinking water is common practice in the drinking water treatment industry. Disinfectants, primarily chlorine, have been used extensively to ensure the safety of drinking water from pathogens. Research in the early 1970's uncovered evidence that application of disinfectants can result in undesirable organic and inorganic disinfection by-products (DBPs) through oxidation/reduction and substitution reactions in natural water In 1979, the United States Environmental Protection Agency (US EPA) promulgated a regulation to control DBP formation.

In 1979, the United States Environmental Protection Agency (US EPA) promulgated a regulation that set a Maximum Contaminant Level (MCL) of 100 $\mu g/L$ for total Trihalomethanes (TTHMs).

In the Stage 1 DBP Rule (DBPR), the US EPA promulgated MCLs for the following DBPs: TTHMs, five haloacetic acids (HAA5), bromate, and chlorite at levels specified in Table 1-1

Table 1-1
Maximum Contaminant Levels for D/DBP

Compound	MCL (mg/L) Stage 1 DBP Rule
Total Trihalomethanes (TTHMs)	0.080
Haloacetic Acids (HAA5)	0.060
Bromate	0.010
Chlorite	1.0

Also under this regulation, Maximum Residual Disinfectant Levels (MRDLs) are established for the most commonly used disinfectants. The MRDLs for Stage 1 of the DBP Rule are specified in Table 1-2.

The US EPA developed the *Technologies and Costs for the Control of Disinfection By-Products* (US EPA, 1998c) to support development of the DBPR and to develop cost estimates for the compliance technologies. Readers should refer to this document to obtain background information on the chemistry of DBP formation and applicable treatment technologies.

Table 1-2
Maximum Residual Disinfectant Levels for D/DBP

Compound	MRDLs Stage 1 DBP Rule
Chlorine (as Cl_2)	4.0 mg/L
Chloramine (as Cl_2)	4.0 mg/L
Chlorine Dioxide (ClO_2)	0.8 mg/L

1.2 PURPOSE

The purpose of this document is to examine the application and costs associated with the use of Point-of-Entry (POE) and Point-of-Use (POU) devices as treatment technologies for control of DBPs regulated by the DBPR. The POE/POU devices examined in this document include the following:

- Reverse osmosis (RO); and
- Granular activated carbon (GAC).

This document develops cost estimates for the control of TTHM and HAA5 with these two types of POE/POU devices. The compliance technology for the MRDLs, and bromate, and chlorite MCLs is controlled by process operations.

Estimates were developed for the five smallest US EPA flow categories for POU devices and the three smallest US EPA flow categories for POE devices, as shown in Table 1-3. Economies of scale allow centralized treatment to be less expensive than POE/POU devices for use by larger flow categories; therefore, POE/POU estimates are not provided for all twelve US EPA flow categories.

1.3 POINT-OF-ENTRY AND POINT-OF-USE DEVICES

The US EPA is not listing POE and POU devices as compliance technologies for the Surface Water Treatment Rule (SWTR). Section 1412 (b)(4)(E)(ii) of the 1996 SDWA specifically prohibits POU devices as compliance technologies for microbial contaminants. The National Research Council, a principal operating agency of the National Academy of Sciences, advises that POE devices not be used for disinfection purposes (NRC, 1997). To be effective, water treatment authorities must implement the appropriate technology, and ensure proper maintenance of the units. Water quality monitoring is imperative to ensure all devices are operating efficiently and effectively.

Although the US EPA believes POU devices are affordable (see chapter 5) for small systems, the Agency has reservations listing POU devices as a compliance technology for small systems under DBP Rule because of concerns that they do not address all routes of exposure (e.g., volatilization and dermal exposure from DBPs). Because of these concerns, the US EPA believes additional research is needed prior to listing of POU devices as a compliance technology for small systems. The determination to not list POU devices for DBPs is consistent with the findings in the Small System Compliance Technology Lists included in the Federal Register on August 6, 1998 (63 FR 4203), in which POU devices were not listed for VOCs. When additional information is available, the US EPA may consider listing POU devices as a compliance technology for small systems. POE devices are still considered emerging technologies because of waste disposal and cost considerations and therefore are not considered compliance technologies at this time for small.

Table 1-3
US EPA Flow Categories for Which POE/POU Cost Were Developed

Flow Category	Maximum Population Served	Estimated Number of Households	Adjusted Consumption (kgal/connection)*
1	100	33	83
2	500	167	85
3	1.000	333	85
4	3.300	1,100	85
5	10.000	3,333	89

Note*: The estimated consumption was adjusted upward 15 percent to account for los water due to leaks.

* US EPA 1997 a,b,c

The cost reported for flow categories 2,4 and 5 correspond to the maximum population reported for the three population-based size categories of small systems as outlined in 1996 Safe Drinking Water Act (SDWA). The 1996 SDWA size categories are as follows:

- 10,000 or fewer but more than 3,301;
- 3,300 or fewer but more than 501; and
- 500 or fewer but more than 25.

1.3.1 Point-of-Entry Devices

Point-of-Entry (POE) devices provide treatment for all the water entering a dwelling or house. POE devices, compared to POU devices, provide an increased level of protection against acute health risks and exposure to contaminants (i.e. volatile organic compounds) via inhalation and dermal contact. Thus, POE devices are more applicable in situations where contaminants may cause health effects through non-ingestion pathways because all the water entering the dwelling receives treatment. Water test information is needed in all POE applications to ensure proper application of the technology (Johnson, 1996). Monitoring and service of POE units is critical to ensure proper performance. Flow meters and seasonal monitoring are essential components of the overall maintenance scheme to gather information regarding water use and its effects on the POE system. This attention, especially during the first year of service, can result in a lower overall cost of maintenance to the water treatment authority (Johnson, 1996).

1.3.2 Point-of-Use Devices

Point-of-Use (POU) devices are utilized for treatment of water meant only for consumption. They are usually attached to household faucets. There are several different device alternatives including: faucet-mounted units, counter-top units, in-line and line bypass units. Counter-top units are not considered a compliance technology since their mode of operation creates a high potential for bacterial contamination. Further, faucet-mounted units may not prove applicable as a compliance technology due to a relatively short contact time. Therefore, this document examines and develops cost for in-line and line bypass POU devices as the only viable alternatives for meeting the DBP Stage 1 MCLs. POU devices may require high levels of monitoring, verification, and awareness of the various reactants produced to maximize disinfectant qualities while minimizing the production of odor from breakpoint and nitrogen trichloride production (Harrington, 1996).

1.4 STANDARDS FOR POE/POU UNITS

The cost estimates developed by the analysis and presented in this document meet the following requirements outlined in the SDWA, Section 1412 (b)(4)(E)(ii):

- POE/POU treatment units shall be owned, controlled, and maintained by the public water system or by a person under contract with the public water system; and
- No POE/POU unit may be included on the list of affordable technologies, treatment technique, and other means of compliance with an MCL or treatment technique unless it is equipped with mechanical warnings to ensure that customers are automatically notified of operational problems; and
- The use of POE/POU devices to achieve compliance with a MCL for a microbial contaminant (or an indicator of a microbial contaminant) is strictly prohibited.

The SDWA also requires POE/POU units be independently certified as having met applicable American National Standards Institute (ANSI) standards prior to being accepted for compliance with a MCL or treatment technique requirement. In listing any technology, treatment technique, or other means pursuant to this clause, the US EPA is required to consider the quality of source water to be treated. The following standards have been established by ANSI/NSF for POE/POU units examined in this document.

1. ANSI/NSF 42 - Aesthetic effects,
2. ANSI/NSF 53 - Health effects;
3. ANSI/NSF 55 - Ultraviolet microbiological treatment
4. ANSI/NSF 58 - Reverse Osmosis Treatment systems; and

Other organization have adopted standards for POE/POU units. The Water Quality Association (WQA) standards for household and commercial water filters include water filters (S-200-73), and RO systems (S-300-84). Standard test to examine the operational parameters of RO (D4194-82) and GAC(D3922-80) units have been developed by The American Society for Testing and Materials (ASTM). The analysis presented in this document assumes that water treatment authorities will only select devices certified under NSF Standards and other applicable technology standards.

1.5 DOCUMENT ORGANIZATION

This document is organized according to the following sections:

- Section 2 - **DEVELOPMENT OF COSTS:** provides the basis for cost development including discussion of cost indices, amortization factors, and curve fitting analysis.
- Section 3 - **REVERSE OSMOSIS:** provides a short summary including process description, design criteria and cost tables for this technology.
- Section 4 - **GRANULAR ACTIVATED CARBON:** provides a short summary including process description, design criteria and cost tables for this technology
- Section 5 - **COST ANALYSIS:** provides a short discussion regarding curve fitting, and break-point analysis as well as affordability criteria assessment.
- Section 6 - **REFERENCES:** provides the citations for the references used in the preparation of this addendum.
- Appendix A - provides cost development spreadsheets and regression analysis curves for the cost estimates developed in this document.
- Appendix B - provides a graphically depiction of the break-point analysis.

2.1 BASIS FOR COST ESTIMATES

An extensive literature search was conducted to identify applicable POE/POU technologies for DBP control. RO and GAC were the only applicable technologies identified. The cost developed for POU Reverse Osmosis and GAC systems in this document are based upon original equipment manufacturer (OEM) information collected in July of 1998 The cost developed for POE Reverse Osmosis and GAC systems are based upon an 1998 draft document developed by the US EPA. The document is entitled, *Cost Evaluation of Small System Compliance Options: Point-of-Use and Point-of-Entry Treatment Units (US EPA, 1998a).* The cost outlined in this document are in 1997 dollars These cost were escalated to 1998 dollars utilizing the Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) and the Engineering News Record's (ENR) Skilled Labor Index. OEM data was deemed most appropriate for cost development since it best represents current practice in both manufacturing techniques and system design. The OEM data provided detailed information on capital cost, installation, membrane replacement and expected life, yield, and expected unit life. The costs generated in this report are limited to general design and operation criteria specified from vendors. The cost do not include allowances for customization due to variances in source water quality Where applicable, volume discounts are applied to cost. The following detailed assumptions are based upon information provided by OEMs, contractor expertise, and the 1998 draft cost evaluation document for POE/POU treatment units (US EPA, 1998a).

2.1.1 Installation Assumptions

The installation of the POE/POU devices will be performed by trained water treatment personnel only. It is assumed that POU units are installed under the sink and POE units are installed in the garage or basement. Any additional materials required for the installation of the equipment (i.e. special site considerations) are not detailed in the cost estimate. However, a contingency fee of 15 percent has been added to capital and installation costs to account for unique characteristics at each installation site. This contingency fee is based upon the percentage added to capital cost for site work and interface piping detailed in the WATERCO$T Model (US EPA, et al. 1986). It is also assumed that training or necessary training materials (i.e. manuals, instructional videos) will be provided by the vendor to permit system personnel to conduct installation and routine maintenance of the system.

Installation of POE and POU units is assumed to require three and one hour(s) labor, respectively including travel time. POU unit installation is to be conducted by minimally skilled labor while POE unit installation is assumed to be conducted by skilled labor. An additional two hours per day of labor is estimated for preparation. All installation costs are based on an eight hour work day or forty hours per week per employee. Installation includes full assembly of the unit and testing to ensure proper operation. Based upon these assumptions, six POU or two POE units can be installed per water treatment employee per day.

2.1.2 Capital Cost Assumptions

Capital cost estimates are based upon OEM data. The basic components included in the estimation of capital cost are as follows

- POU/POE unit;
- All necessary piping, hardware, tubing and house wrench;
- Valve and automatic shut-off device (to comply with SDWA Section 1412 (b)(4)(E)(ii);
- and Ultraviolet Light disinfection unit (POE GAC units only).

More detailed design criteria are provided in each section addressing specific technologies. Capital cost estimates do not include shipping and handling fees. The amortization of capital cost is based upon the expected unit life as documented by the OEMs at an interest rate of 3, 7 and 10 percent. The assumed lifetime for POE/POU units is 5 and 10 years, respectively. The following formula is used in the calculation of the appropriate capital recovery rate:

Capital Recovery Rate: $(1 + i)^N / (1 + i)^N - 1$

Where: N = lifetime of unit
i = interest rate

2.1.3 Operation and Maintenance Assumptions

2.1.3.1 Maintenance Cost Assumptions

All maintenance will be conducted by trained water treatment personnel. It is recommended that water treatment facilities conduct pilot-tests to determine the volume of water treated prior to breakthrough. This is important since microbiological, chemical, and physical properties of a community's water supply can have a significant effect upon replacement frequency. POU filter replacement is assumed to be quarterly while POE filter replacement is assumed to be on a yearly basis. POU and POE unit maintenance, including testing, calibration, cartridge, media or filter replacement, and travel time, is assumed to require 45 minutes and 2 hours, respectively. POU unit maintenance is to be conducted by minimally skilled labor while POE unit maintenance is assumed to be conducted by skilled labor. An additional 2 hours is added per day for daily preparation. There are no shipping and handling cost included in this analysis. Based upon these assumptions, 3 POE or 8 POU units can undergo maintenance per day per employee. Table 2-1 provides cost estimates provided by OEMs for replacement materials. No additional cost for electricity used in conjunction with the operation of a UV lighting unit for POE devices is included. Administrative items (i.e. office supplies, record keeping, and other items) are estimated to add $15.00 to O&M cost per household.

2.1.3.2 Labor Cost Assumptions

Labor is based on a 40 hour work week at 8 hours per personnel per day The labor rates assumed for the estimation of cost are based on escalated 1997 values reported in the Information Collection Rule for Public Water System Supervision Program, still under review These rates include $14 94 for minimal skilled labor and $28 78 for skilled labor. Labor associated with administrative items (i e. monitoring sample tracking) is assumed to be 1 hour per household per year

Table 2-1
POU Cost Data for Replacement Components

Device	Component	Cost	Expected Life
POU Reverse Osmosis	Membrane Cost	$ 79.50	18-24 months
	Chlorine/Sediment Pre- Filter	$ 10.65	3 months (250 gallons)
	Carbon Post-Filter	$ 9.80	6 months (500 gallons)
POU GAC	Activated Carbon Filters	$ 40.00	12 months

2.1.3.3 Monitoring Cost Assumptions

Monitoring will be conducted to ensure proper operation and compliance with the DBP Stage 1 MCLs. For surface water systems serving less than 500 people, one sample from one dwelling will examined annually. For surface water systems serving between 501 and 9,999 people, one sample from one dwelling once per quarter will be examined. Ground water systems serving less than 500 people will follow the same monitoring scheme as outlined above for surface water systems. However, ground water systems serving between 501 and 9,999 people will monitor one system in one dwelling on an annual basis. It is assumed that sampling will be conducted at the time of maintenance. It is also assumed sampling will require 15 minutes added labor for POU units and 30 minutes for POE units. An additional hour is also estimated for preparation time. The testing of the sample will include screening for TTHM and HAA5 levels. Table 2-2 details the cost associated with analyzing the samples.

Table 2-2
Sampling Cost Estimates

Contaminant	Cost
TTHMs	$ 100.00
HAA5	$ 150.00

2.1.3.4 Waste Costs Assumptions

Waste associated with POU Reverse Osmosis and GAC units is assumed to be negligible due to the frequency of filter replacement. In the case of POE Reverse Osmosis and GAC units, waste is assumed to be collected and discharged to a publically owned treatment works. The waste volume is based upon a 25 percent reject volume. Cost were developed from the equations presented in the *Small Water Systems Byproducts Treatment and Disposal Cost Document* (US EPA, 1993) Cost were escalated to 1998 dollars based on Engineering News Record indexes and amortized at 3, 7 and 10 percent interest for 20 years It is to be noted, that the cost associated with waste disposal are estimated based on average waste production estimates for non-radioactive sludges and brines The actual waste constituents may differ due to source water parameters.

2.1.4 Additional Assumptions

The cost developed in this document only assumed the use of POU at one faucet. Providing more than one POU unit per dwelling becomes cost prohibitive, with the result that POE devices become the recommended alternative for treatment of the dwellings water supply. To ensure compliance with the SDWA section 1412(b)(4)(E)(ii), all POE/POU devices will be equipped with a mechanical warning and shut-off device to ensure users are automatically notified of operational problems. RO units are assumed to be equipped with an in-line Total Dissolved Solids monitor instead of a water meter so inorganic breakthrough can be determined by conductivity. The estimated number of units required for each US EPA flow category is based on the maximum possible number of dwellings in each category given an average of 3 individuals per household at the maximum estimated population (i.e. 33 units for flow category 1). An average water consumption per individual per household of 1 gallon is assumed for drinking and cooking. The annual total water assumed per connection for POE devices is reported in Table 1-3. All units are assumed to be owned and operated by the water treatment system and any tampering with the device by the user is prohibited.

3.1 PROCESS DESCRIPTION: REVERSE OSMOSIS

Reverse Osmosis (RO) involves forcing the contaminated source water through a semi-permeable membrane By maintaining a pressure gradient greater than the osmotic pressure of the feed. contaminants are rejected by the membrane and discharged in a reject stream. Periodic flushing of the reject water is required to reduce the potential for scale formation on the membrane Depending upon the source water quality, pre-treatment may be required to reduce harm to the membrane due to disinfectant residuals such as chlorine.

3.1.1 Parameters to Ensure Peak Reverse Osmosis Performance

Slovak and Hafner (1996) detail six water-quality parameters that effect the performance of RO units. They are:

1. **Total Dissolved Solids (TDS).** The level of TDS in feed water should be examined before choosing the type of membrane to be utilized, since the rejection rate varies with each membrane. TDS can cause osmotic "back pressure," which can reduce the effective feed water pressure.
2. **Feedwater pressure.** The net pressure (net pressure = feed pressure - back pressure - osmotic pressure) is directly proportional to the RO production rate and effects the percent rejection of TDS. For cellulose POU membranes, the minimum net pressure should be 25 psi. For thin-film, (TF) membranes the recommended minimum net pressure is 15 psi.
3. **Feedwater temperature.** Temperature can effect the viscosity of water and thus the RO production rate. For the determination of a production rate, the industry standard recommends 77° F (25° C). The determination of temperature is crucial to ensure membrane degradation does not occur. The maximum operating temperature for cellulose acetate (CA) and cellulose triacetate (CTA) membranes is 85° F (29° C), and for TF membranes, 100° F (38° C).
4. **Feedwater pH.** At pH levels exceeding 8.0, cellulosic membranes (CA, CTA and CA/CTA blends) can lose their rejection of TDS because of deterioration due to hydrolysis. TF membranes can safely operate at pH levels up to 11.0.
5. **Water disinfection.** Disinfectants such as chlorine, chloramines or ozone can cause membrane deterioration. Cellulose membranes resist the effects of chlorine and other chemical oxidizers but can be deteriorated by certain bacteria in non-disinfected supplies. Most TF membranes are immune to bacterial deterioration but do not resist free chlorine and other disinfectants well.
6. **Impurities.** Water analysis is crucial prior to adopting an RO treatment strategy to ensure no impurities are present (i.e. excessive hardness, manganese, alum etc.).

3.1.2 Pretreatment for Reverse Osmosis

Paul (1994) suggests that pre-treatment is critical prior to the application of an TF composite membrane for source waters disinfected by chlorine or chloramines To reduce chlorine and chloramines prior to the application of RO, activated carbon (AC) provides the most cost-effective solution However, the greatest disadvantage to AC treatment is the possibility for microorganism growth The issue of the risk surrounding bacterial colonization is examined in detail in Section 4 1 1 In the case of chlorine and chloramine, cellulose membranes are resistant to their oxidizing pressures (Harrington, 1996).

3.2 DESIGN CRITERIA

Table 3-1a and b details the basic design criteria upon which cost estimations are based for treatment with POE/POU RO devices.

Table 3-1a
Design Criteria for POE Reverse Osmosis Devices

POE	
Capital	(1) POE Reverse Osmosis Unit (1) Water meter with automatic warning and shut-off device. Installation hardware included
Operation & Maintenance	All necessary replacement components Replacement assumed to occur every 12 months Sampling as described in Section 2.1.3.3 of this document

Table 3-1b
Design Criteria for POU Reverse Osmosis Devices

POU	
Capital	(1) 5-micron activated carbon pre-filter (1) activated carbon post-filter (1) TFC membrane (horizontal) (1) 2.5 gallon storage tank, Air gap faucet, Water meter with automatic warning and shut-off device Installation hardware included
Operation & Maintenance	Replacement of pre- and post-filter every 3-months Replacement of membranes every 18 months Sampling as described in Section 2.1.3.3 of this document

The operational performance data provided by the OEM demonstrates a greater than 95 percent reduction in TTHMs utilizing POU Reverse Osmosis at an average influent concentration of 200 to 300 $\mu g/L$. The operational specifications also call for the replacement of the pre-filter every 3 months or 250 gallons, the post-filter every 6 months or 500 gallons, and the membrane every 18 months or 1,500 gallons

3.3 TOTAL COSTS

Table 3-2 and 3-3 provides cost estimates for DBP control with POE/POU Reverse Osmosis devices. A more detailed cost development description is provided in Appendix A-1 and A-2 for ground water systems and Appendix A-5 and A-6 for surface water systems.

Table 3-2
Total Cost for POE Reverse Osmosis Devices

Estimated Population	Estimated Flow (MGD)	Estimated Number of Households	Capital Cost (M$)	Annual O&M Cost (¢/kgal)	Annual Total Cost @ 3% (¢/kgal)	Annual Total Cost @ 7% (¢/kgal)	Annual Total Cost @ 10% (¢/kgal)
GROUND WATER SYSTEMS							
100	0.01	33	0.310	942	2,259	2.543	2.774
500	0.05	167	1.508	882	2.126	2,393	2.610
1.000	0.10	333	2.920	863	2.072	2.331	2.541
SURFACE WATER SYSTEMS							
100	0.01	33	0.310	942	2.259	2.543	2.774
500	0.05	167	1.508	882	2,126	2,393	2.610
1.000	0.10	333	2.920	867	2.075	2.335	2.545

Table 3-3
Total Cost for POU Reverse Osmosis Device

Estimated Population	Estimated Flow (MGD)	Estimated Number of Households	Capital Cost (M$)	Annual O&M Cost (¢/kgal)	Annual Total Cost @ 3% (¢/kgal)	Annual Total Cost @ 7% (¢/kgal)	Annual Total Cost @ 10% (¢/kgal)
GROUND WATER SYSTEMS							
100	0.01	33	0.016	247	373	387	399
500	0.05	167	0.067	218	321	333	343
1,000	0.10	333	0.133	209	311	323	332
3,300	0.33	1,100	0.437	208	310	322	331
10,000	1.00	3,333	1.323	193	291	302	311
SURFACE WATER SYSTEMS							
100	0.01	33	0.016	247	373	387	399
500	0.05	167	0.067	218	321	333	343
1,000	0.10	333	0.133	212	314	326	336
3,300	0.33	1,100	0.437	209	311	323	332
10,000	1.00	3,333	1.323	194	291	303	311

4.1 PROCESS DESCRIPTION: GAC

POE/POU activated carbon devices are widely used and typically the easiest to maintain Activated carbon is produced in block, granular or powdered form. although granular activated carbon is the most common. It is produced by heating carbonaceous substances in the absence of air, resulting in an absorbent material that is highly porous (Gordon et. Al , 1997) GAC removes contaminants by an adsorption process influenced by contaminant solubility and affinity for the carbon surface Water conditions, such as temperature and pH, can greatly effect the adsorption capacity of GAC. GAC is able to improve water conditions through the removal of organic and solvent contaminants, including volatile organic compounds (VOCs) and trihalomethanes (THM), along with many other organic chemicals (Gordon, et al., 1997). GAC effectively removes chlorine improving water taste and reducing odor. Being an effective remover of chlorine, GAC is a common pretreatment option in the case of TF membranes (See Section 3.1.3). The removal of chlorine does pose some concern due to the potential for bacterial growth. GAC filters also need to be replaced frequently to prevent contaminant breakthrough.

4.1.1 Bacterial Colonization of POE/POU Devices

Bell et al (1984), in a study of home water treatment systems, reported a significant increase in test-unit effluent heterotrophic-plate-count (HPC) densities compared to influent HPC levels after overnight and 2-day stagnation periods. Additionally, Reasoner et al (1987) found high levels of HPC bacteria in GAC effluent water in laboratory tap water. This suggests that GAC filters are susceptible to colonization by heterotrophic bacteria. Further, Snyder et al. (1995) noted that these high HPC densities may prevent pathogenic bacteria colonization of the GAC filter beds. It is to be note no increase in illness incident was connected to the exposure described in these studies. It is recommended that consumers run water for 30 seconds prior to use to allow the removal of bacteria easily washed off the filter media. POU contamination from bacteria is not considered significant due to the frequency of filter replacement, which was outlined in section 2.1.3.1. Bacterial growth in POU systems can be controlled through proper sizing of the unit to prevent long tank holding times of treatmented water. If stagnation does occur (i.e., after a vacation), proper flushing of the system should reduce the potential levels of bacterial contamination (Schlafer, et al., 1997).

Potential bacterial contamination can also occur due to backflow (Cheesebrow, 1995). All POU units used for the basis of cost estimation include a air gap faucet to protect against potential backwash contamination. For POE devices utilizing GAC, the cost of a ultraviolet unit module has been added to capital for post treatment mediation of bacteria.

4.2 DESIGN CRITERIA

Table 4-1a and b details the basic design criteria upon which cost estimations are based for treatment with POE/POU GAC devices.

Table 4-1a
Design Criteria for POE GAC Devices

POE	
Capital	(1) POE GAC Unit (1) Water meter with automatic warning and shut-off device. (1) UV light Installation hardware included
Operation & Maintenance	All necessary replacement components Replacement assumed to occur every 12 months Sampling as described in Section 2.1.3.3 of this document

Table 4-1b
Design Criteria for POU GAC Devices

POU	
Capital	(2) Activated carbon filters (1) Air gap faucet (1) Water meter with automatic warning and shut-off device Installation hardware included
Operation & Maintenance	All necessary replacement components Filter replacement is assumed to occur every 3 months. Sampling as described in Section 2.1.3.3 of this document

The operational performance data provided by the OEM demonstrates a 95 percent reduction in TTHMs utilizing POU GAC at an average influent concentration of 300 $\mu g/L$. The operational specifications also call for the replacement of the filter every 4 months or approximately 250 gallons. However, if DBP concentrations are very high, the water treatment system may wish to consider the application of POE/POU RO instead of POE/POU GAC.

4.3 TOTAL COSTS

Table 4-2 and 4-3 provides cost estimates for DBP control with POE/POU GAC devices. A more detailed cost development description is provided in Appendix A-3 and A-4 for ground water systems and Appendix A-7 and A-8 for surface water systems.

Table 4-2
Total Cost for POE GAC Devices

Estimated Population	Estimated Flow (MGD)	Estimated Number of Households	Capital Cost (M$)	Annual O&M Cost (¢/kgal)	Annual Total Cost @ 3% (¢/kgal)	Annual Total Cost @ 7% (¢/kgal)	Annual Total Cost @ 10% (¢/kgal)
GROUND WATER SYSTEMS							
100	0.01	33	0.091	474	855	939	1,007
500	0.05	167	0.368	442	745	810	863
1,000	0.10	333	0.731	440	742	807	859
SURFACE WATER SYSTEMS							
100	0.01	33	0.091	474	855	939	1,007
500	0.05	167	0.368	442	745	810	863
1,000	0.10	333	0.731	443	745	810	863

Table 4-3
Total Cost for POU GAC Device

Estimated Population	Estimated Flow (MGD)	Estimated Number of Households	Capital Cost (M$)	Annual O&M Cost (¢/kgal)	Annual Total Cost @ 3% (¢/kgal)	Annual Total Cost @ 7% (¢/kgal)	Annual Total Cost @ 10% (¢/kgal)
GROUND WATER SYSTEMS							
100	0.01	33	0.007	259	312	318	323
500	0.05	167	0.031	239	286	291	296
1,000	0.10	333	0.060	229	276	281	286
3,300	0.33	1,100	0.198	228	275	280	284
10,000	1.00	3,333	0.599	213	257	263	267
SURFACE WATER SYSTEMS							
100	0.01	33	0.007	259	312	318	323
500	0.05	167	0.031	239	286	292	296
1,000	0.10	333	0.060	233	279	285	289
3,300	0.33	1,100	0.198	229	276	281	285
10,000	1.00	3,333	0.599	214	258	263	267

5.1 CURVE FITTING ANALYSIS

The total cost estimates generated at 3,7, and 10 percent interest were plotted on a scatter graph Regression analysis was than performed to develop a cost equation for the estimation of costs associated with DBP control by POE/POU RO and GAC devices at the various interest rates specified The independent parameter in each case is the estimated number of households The graphs are provided in the Appendix A (A-9 through A-16).

5.2 BREAK-POINT ANALYSIS

A break-point analysis was conducted to examine at what number of households, POE/POU treatment strategies may prove to be more cost effective than comparable centralized treatment options. The technologies (data source) analyzed included the following:

- POE Reverse Osmosis and POE GAC (vendor);
- POU Reverse Osmosis and POU GAC (vendor);
- Centralized nanofiltration (1998 Technologies & Cost document);
- Centralized GAC-10 minute EBCT (1998 Technologies & Cost document), and
- Centralized GAC-20 minute EBCT (1998 Technologies & Cost document).

Centralized treatment costs, based in 1997 dollars, were escalated to 1998 dollars using the ENR's Building Cost Index and the BLS's Chemical and Allied Products Index. The flow criteria for which centralized treatment costs were developed has been translated into an estimated number of households based upon the adjusted flow per connection reported in Table 1-3. This data is reported in Table 5-1.

Table 5-1
Translation of Centralized Treatment Cost

Average Flow (MGD)*	Maximum Assumed Population	Estimated Number of Households
0.0056	100	25
0.024	500	103
0.086	1,000	369
0.23	3,300	988
0.70	10,000	2871

* Source: 1998 Technologies & Cost document

The data analyzed included total costs at 7 percent interest for an estimated lifetime of 5, 10, and 20 years for POU, POE, and centralized treatment, respectively. Table 5-2 and 5-3 details the cost break-points in terms of estimated households served and cost per 1000 gallons treated for POE/POU devices verse comparable centralized treatment options. A graphical depiction is provided in appendix B-1 through B-4 for ground water systems and appendix B-5 through B-8 for surface water systems.

Table 5-2
Break-Point Analysis - Ground Water Systems
(# of Households / ¢/kgal)

	Centralized Treatment		
	GAC-10min EBCT	GAC-20min EBCT	Nanofiltration
POE Reverse Osmosis	*	*	*
POU Reverse Osmosis	49/367	490/328	*
POE GAC	*	51/904	*
POU GAC	69 / 305	715 / 279	1125 / 274

* No break-point exists

Table 5-3
Break-Point Analysis - Surface Water Systems
(# of Households / ¢/kgal)

	Centralized Treatment		
	GAC-10min EBCT	GAC-20min EBCT	Nanofiltration
POE Reverse Osmosis	*	*	*
POU Reverse Osmosis	48 / 368	489 / 329	*
POE GAC	*	51 / 904	*
POU GAC	69 / 306	712 / 280	1105 / 275

* No break-point exists

5.3 AFFORDABILITY CRITERIA ASSESSMENT

The costs developed for POE/POU devices in this document were compared to the affordability criteria set forth in the *National-Level Affordability Criteria Under the 1996 Amendments to the Safe Drinking Water Act, Draft Report*, (US EPA, 1998b). The affordability outlined in this document is pursuant to Section 1412(b)(4) of the SDWA. The cost associated with SDWA compliance technologies for community water systems (CWS) are deemed affordable if the following are met

- the cost associated with their application are affordable to the average household.
- the costs are within a certain percentage of median household income; and
- the costs are comparable to other household expenditures.

The need to examine the ability-to-pay of residential customers for a treatment option is important in determining the ability of small systems to pass along the cost of compliance with an operational or treatment requirement.

5.3.1 Determination of Household Affordability

Table 5-6 details the affordability assessment for the application of POE/POU devices for control of DBPs under Stage I of the DBP rule. The cost associated with POE/POU technology are based upon total cost (¢/kgal) at 7 percent interest. The baseline treatment cost and median household income are reported in Table 5-4 from the draft affordability document (US EPA 1998b) Baseline reported values are assumed to represent cost per household prior to the adoption of POE/POU devices for DBP control. The median household income and water bills were reported in 1995 dollars. These values were escalated based upon the Engineering News Records index for skilled labor and the Bureau of Labor Statistics Consumer Price Index for water and sewerage maintenance, respectively. The 1998 values are reported in parentheses in Table 5-4.

Table 5-4
National Level Affordability Criteria
Cost Basis 1995 Dollars (Cost Basis 1998 Dollars)

System Size Population Served	Baseline			Affordability Threshold (2.5% of MHI)	Available Expenditure Margin ($/HH/yr. Increase)
	Median Household Income (MHI)	Median Water Bills ($/HH/yr)	Median Water Bills (%MHI)		
25-500	30,785 (33,094)	211 (234)	0.69 (0.71)	770 (827)	559 (593)
501-3,300	27,058 (29,087)	184 (204)	0.68 (0.70)	676 (727)	492 (523)
3,301-10,000	27,641 (29,714)	181 (201)	0.65 (0.68)	691 (743)	510 (542)

Source: 1998 Draft SDWA Affordability Document

The US EPA has established an affordability threshold associated with water cost for households of 2.5 percent of household income. In accordance with this affordability criteria, POU Reverse Osmosis, and POU GAC are deemed affordable technology options. Also, these costs are in-line with consumer expenditures as a percent of income for such items as electricity (2.4 percent), alcohol, and tobacco (1.5 percent) and reading and education (1.7 percent). In contrast, the costs associated with POE Reverse Osmosis and POE GAC are estimated to be 7.1 and 2.9 percent of household income, respectively. Therefore, the cost associated with POE Reverse Osmosis and POE GAC could pose a potential burden upon households and CWS's.

The costs developed for POE/POU devices in this document are based on a range of households. Cost curves were generated for both capital and O&M costs with the number of households as the independent parameter. A subset of data from the Community Water Supply Survey(US EPA, 19987 a,b,c) provided information regarding residential connections. This data was used to determine the median number of connections within each size category. The number of connections was assumed to be the number of households for each size category under the SDWA. The resultant number of households and on which the total annual composite costs for the three size categories under the SDWA, detailed in Table 5-6, are reported in Table 5-5.

Table 5-5
Number of Households by Size Category for POE/POU Options

SDWA Size Categories	Population		Median Number of Households
	Minimum	Maximum	
1	25	500	50
2	501	3,300	425
3	3,301	10,000	1935

Table 5-6
Summary of POE/POU Cost and Household Income

Population	Treatment Option	Composite Annual Cost for POE/ POU ($/HH)	Annual Baseline Cost ($/HH)*	Total Cost ($)	Average Median HH Income ($)*	Cost as a % of HH Income
GROUND WATER						
25-500	POE RO	2,124	234	2,358	33,094	7.1
	POU RO	309		543		1.6
	POE GAC	713		947		2.9
	POU GAC	276		510		1.5
501-3,300	POU RO	263	204	467	29,087	1.6
	POU GAC	234		438		1.5
3,301-10,000	POU RO	258	201	459	29,714	1.5
	POU GAC	230		431		1.4
SURFACE WATER						
25-500	POE RO	2,128	234	2,362	33,094	7.1
	POU RO	317		551		1.7
	POE GAC	717		951		2.9
	POU GAC	284		518		1.6
501-3,300	POU RO	264	204	468	29,087	1.6
	POU GAC	235		439		1.5
3,301-10,000	POU RO	258	201	459	29,714	1.5
	POU GAC	230		431		1.5

* Source *National-Level Affordability Criteria Under the 1996 Amendments to the Safe Drinking Water Act. (Escalated to 1998 dollars)*

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Appendix A

Figure A-1
Cost Development for Point-of-Entry Reverse Osmosis
(Ground Water)

Capital Cost

Amortization (Based on 10 years) Factor: 3% 0.1172305; 7% 0.1423775; 10% 0.1627454

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Capital Cost for POTW Discharge ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	RO	POE	Vendor	33	$255,348	$10,143	$39,824	$3,955	$309,270	$36,058	$43,843	$50,153	$1,519.[illegible]
2	RO	POE	Vendor	167	$1,256,174	$51,331	$196,126	$3,955	$1,507,586	$176,537	$214,457	$245,171	$1,468.11
3	RO	POE	Vendor	333	$2,433,299	$102,355	$380,348	$3,955	$2,919,957	$342,110	$415,546	$475,030	$1,426.[illegible]

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Annual POTW Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	RO	POE	Vendor	33	$21,983	$358	$1,445	$2,028	$25,813	$782.21	942
2	RO	POE	Vendor	167	$108,843	$358	$7,311	$8,741	$125,252	$750.01	882
3	RO	POE	Vendor	333	$212,241	$415	$14,579	$17,057	$244,292	$733.61	863

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/Connection)
1	RO	POE	Vendor	33	2,259	2,543	2,774	83
2	RO	POE	Vendor	167	2,126	2,393	2,610	85
3	RO	POE	Vendor	333	2,072	2,331	2,541	85

Figure A-2
Cost Development for Point-of-Use Reverse Osmosis
(Ground Water)

Capital Cost

Amortization (Based on 5 years)	3%	7%	10%
Factor:	0.2183546	0.2438907	0.2637975

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	RO	POU	Vendor	33	$12,969	$672	$2,046	$15,687	$3,425	$3,826	$4,138	$125.40
2	RO	POU	Vendor	167	$54,943	$3,332	$8,741	$67,016	$14,633	$16,345	$17,679	$105.86
3	RO	POU	Vendor	333	$109,557	$5,812	$17,305	$132,674	$28,970	$32,358	$34,999	$105.10
4	RO	POU	Vendor	1100	$361,900	$18,077	$56,997	$436,974	$95,415	$106,574	$115,273	$104.79
5	RO	POU	Vendor	3333	$1,096,557	$53,779	$172,550	$1,322,886	$288,858	$322,640	$348,974	$104.70

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	RO	POU	Vendor	33	$5,468	$322	$988	$6,778	$205.38	247
2	RO	POU	Vendor	167	$25,619	$322	$5,000	$30,940	$185.27	218
3	RO	POU	Vendor	333	$48,752	$322	$9,970	$59,044	$177.31	209
4	RO	POU	Vendor	1100	$160,867	$322	$32,934	$194,123	$176.48	208
5	RO	POU	Vendor	3333	$473,846	$322	$99,790	$573,9[illegible]	$172.20	193

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	RO	POU	Vendor	33	373	387	399	83
2	RO	POU	Vendor	167	321	333	343	85
3	RO	POU	Vendor	333	311	323	332	85
4	RO	POU	Vendor	1100	310	322	331	85
5	RO	POU	Vendor	3333	291	302	311	89

Figure A-3
Cost Development for Point-of-Entry Granular Activated Carbon
(Ground Water)

Capital Cost — **Amortization (Based on 10 years) Factor:** 3%: 0 1172305; 7%: 0 1423775; 10%: 0 1627454

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Capital Cost for POTW Discharge ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% [illegible]
1	GAC	POE	Vendor	33	$72,933	$2,544	$11,322	$3,955	$90,753	$10,441	$12,731	$14,591	[illegible]
2	GAC	POE	Vendor	167	$303,971	$12,876	$47,527	$3,955	$368,328	$42,981 51	$52,252	$59,765	[illegible]
3	GAC	POE	Vendor	333	$606,121	$25,674	$94,769	$3,955	$730,520	$85,441 41	$103,820	$118,710	[illegible]

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Annual POTW Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	GAC	POE	Vendor	33	$9,159	$358	$1,445	$2,028	$12,990	$393.63	474
2	GAC	POE	Vendor	167	$46,353	$358	$7,311	$8,741	$62,762	$375.82	442
3	GAC	POE	Vendor	333	$92,427	$415	$14,579	$17,057	$124,478	$373 81	440

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	GAC	POE	Vendor	33	855	939	1,007	83
2	GAC	POE	Vendor	167	745	810	863	85
3	GAC	POE	Vendor	333	742	807	859	85

Figure A-4
Cost Development for Point-of-Use Granular Activated Carbon (Ground Water)

Capital Cost

Amortization (Based on 5 years) — 3%, 7%, 10%
Factor: 0.2183546, 0.2438907, 0.2637975

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	GAC	POU	Vendor	33	$5,082	$672	$863	$6,617	$1,445	$1,614	$1,746	$52.90
2	GAC	POU	Vendor	167	$23,380	$3,332	$4,007	$30,718	$6,707	$7,492	$8,103	$48.52
3	GAC	POU	Vendor	333	$46,620	$5,812	$7,865	$60,296	$13,166	$14,706	$15,906	$47.77
4	GAC	POU	Vendor	1100	$154,000	$18,077	$25,812	$197,889	$43,210	$48,263	$52,203	$47.46
5	GAC	POU	Vendor	3333	$466,620	$53,779	$78,060	$598,458	$130,676	$145,958	$157,872	$47.37

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	GAC	POU	Vendor	33	$5,788	$322	$988	$7,097	$215.07	259
2	GAC	POU	Vendor	167	$28,564	$322	$5,000	$33,886	$202.91	239
3	GAC	POU	Vendor	333	$54,626	$322	$9,970	$64,918	$194.95	229
4	GAC	POU	Vendor	1100	$180,271	$322	$32,934	$213,527	$194.12	228
5	GAC	POU	Vendor	3333	$532,640	$322	$99,790	$632,752	$189.84	213

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	GAC	POU	Vendor	33	312	318	323	83
2	GAC	POU	Vendor	167	286	291	296	85
3	GAC	POU	Vendor	333	276	281	286	85
4	GAC	POU	Vendor	1100	275	280	284	85
5	GAC	POU	Vendor	3333	257	263	267	89

Figure A-5
Cost Development for Point-of-Entry Reverse Osmosis
(Surface Water)

Capital Cost

Amortization (Based on 10 years)	3%	7%	10%
Factor:	0.1172305	0.1423775	0.1627454

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Capital Cost for POTW Discharge ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	RO	POE	Vendor	33	$255,348	$10,143	$39,824	$3,955	$309,270	$36,058	$43,843	$50,153	$1,519.[illegible]
2	RO	POE	Vendor	167	$1,256,174	$51,331	$196,126	$3,955	$1,507,586	$176,537	$214,457	$245,174	$1,468.11
3	RO	POE	Vendor	333	$2,433,299	$102,355	$380,348	$3,955	$2,919,957	$342,110	$415,546	$475,030	$1,4[illegible]

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Annual POTW Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	RO	POE	Vendor	33	$21,983	$358	$1,445	$2,028	$25,813	$782.21	942
2	RO	POE	Vendor	167	$108,843	$358	$7,311	$8,741	$125,252	$750.01	882
3	RO	POE	Vendor	333	$212,241	$1,430	$14,579	$17,057	$245,307	$736.66	867

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Connection (kgal/connection)
1	RO	POE	Vendor	33	2,259	2,543	2,774	83
2	RO	POE	Vendor	167	2,126	2,393	2,610	85
3	RO	POE	Vendor	333	2,075	2,335	2,545	85

Figure A-6
Cost Development for Point-of-Use Reverse Osmosis
(Surface Water)

Capital Cost — Amortization (Based on 5 years) Factor: 3% 0.2183546; 7% 0.2438907; 10% 0.2637975

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	RO	POU	Vendor	33	$12,969	$672	$2,046	$15,687	$3,425	$3,826	$4,138	$125.10
2	RO	POU	Vendor	167	$54,943	$3,332	$8,741	$67,016	$14,633	$16,345	$17,679	$105.86
3	RO	POU	Vendor	333	$109,557	$5,812	$17,305	$132,674	$28,970	$32,358	$34,999	$105.10
4	RO	POU	Vendor	1100	$361,900	$18,077	$56,997	$436,974	$95,415	$106,574	$115,273	$104.79
5	RO	POU	Vendor	3333	$1,096,557	$53,779	$172,550	$1,322,886	$288,858	$322,640	$348,974	$104.70

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Total O&M Cost ($$)	O&M Cost per HH ($$)	O&M Cost per (c/kgal)
1	RO	POU	Vendor	33	$5,468	$322	$988	$6,778	$205.40	247
2	RO	POU	Vendor	167	$25,619	$322	$5,000	$30,941	$185.27	218
3	RO	POU	Vendor	333	$48,752	$1,290	$9,970	$60,012	$180.22	212
4	RO	POU	Vendor	1100	$160,867	$1,287	$32,934	$195,088	$177.35	209
5	RO	POU	Vendor	3333	$473,846	$1,287	$99,790	$574,923	$172.49	194

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	RO	POU	Vendor	33	373	387	399	83
2	RO	POU	Vendor	167	321	333	343	85
3	RO	POU	Vendor	333	314	326	336	85
4	RO	POU	Vendor	1100	311	323	332	85
5	RO	POU	Vendor	3333	291	303	311	89

Figure A-7
Cost Development for Point-of-Entry Granular Activated Carbon
(Surface Water)

Capital Cost

					Amortization (Based on 10 years)			Factor:	3% 0 1172305	7% 0 1423775	10% 0 1627454		
Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Capital Cost for POTW Discharge ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	GAC	POE	Vendor	33	$72,933	$2,544	$11,322	$3,955	$90,753	$10,441	$12,731	$14,591	[illegible]
2	GAC	POE	Vendor	167	$303,971	$12,876	$47,527	$3,955	$368,328	$42,981 51	$52,252	$59,765	[illegible]
3	GAC	POE	Vendor	333	$606,121	$25,674	$94,769	$3,955	$730,520	$85,441 41	$103,820	$118,710	[illegible]

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Annual POTW Cost	Total O&M Cost ($$)	O&MCost per HH ($$)	O&M Cost per (c/kgal)
1	GAC	POE	Vendor	33	$9,159	$358	$1,445	$2,028	$12,990	$393 63	474
2	GAC	POE	Vendor	167	$46,353	$358	$7,311	$8,741	$62,762	$375 82	442
3	GAC	POE	Vendor	333	$92,427	$1,430	$14,579	$17,057	$125,493	$376 86	443

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	GAC	POE	Vendor	33	855	939	1,007	83
2	GAC	POE	Vendor	167	745	810	863	85
3	GAC	POE	Vendor	333	745	810	863	85

Figure A-8
Cost Development for Point-of-Use Granular Activated Carbon
(Surface Water)

Capital Cost

Amortization (Based on 5 years)	3%	7%	10%
Factor:	0.2183546	0.2438907	0.2637975

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Accum. Unit Price($$)	Installation ($$)	Contigency ($$)	Total Capital Cost ($$)	Amortized @ 3%	Amortized @7%	Amortized @10%	Capital Cost per HH @10% ($)
1	GAC	POU	Vendor	33	$5,082	$672	$863	$6,617	$1,445	$1,614	$1,746	$52.90
2	GAC	POU	Vendor	167	$23,380	$3,332	$4,007	$30,718	$6,707	$7,492	$8,103	$48.52
3	GAC	POU	Vendor	333	$46,620	$5,812	$7,865	$60,296	$13,166	$14,706	$15,906	$47.77
4	GAC	POU	Vendor	1100	$154,000	$18,077	$25,812	$197,889	$43,210	$48,263	$52,203	$47.46
5	GAC	POU	Vendor	3333	$466,620	$53,779	$78,060	$598,458	$130,676	$145,958	$157,872	$47.37

O&M Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Annual Maint. Cost ($$/yr)	Annual Sampling Cost	Annual Admin. Cost	Total O&M Cost ($$)	O&MCost per HH ($$)	O&M Cost per (c/kgal)
1	GAC	POU	Vendor	33	$5,788	$322	$988	$7,098	$215.09	259
2	GAC	POU	Vendor	167	$28,564	$322	$5,000	$33,887	$202.91	239
3	GAC	POU	Vendor	333	$54,626	$1,290	$9,970	$65,886	$197.86	233
4	GAC	POU	Vendor	1100	$180,271	$1,287	$32,934	$214,492	$194.99	229
5	GAC	POU	Vendor	3333	$532,640	$1,287	$99,790	$633,717	$190.13	214

Total Cost

Flow Category	Type of Unit	Point of Application	Source	Number of Households	Total Cost @3% (c/1000gal)	Total Cost @7% (c/1000gal)	Total Cost @10% (c/1000gal)	Adjusted Consumption (kgal/connection)
1	GAC	POU	Vendor	33	312	318	323	83
2	GAC	POU	Vendor	167	286	292	296	85
3	GAC	POU	Vendor	333	279	285	289	85
4	GAC	POU	Vendor	1100	276	281	285	85
5	GAC	POU	Vendor	3333	258	263	267	89

Figure A-9
Total Cost Regression Analysis for
DBP Control in Ground Water
-POE Reverse Osmosis Devices-

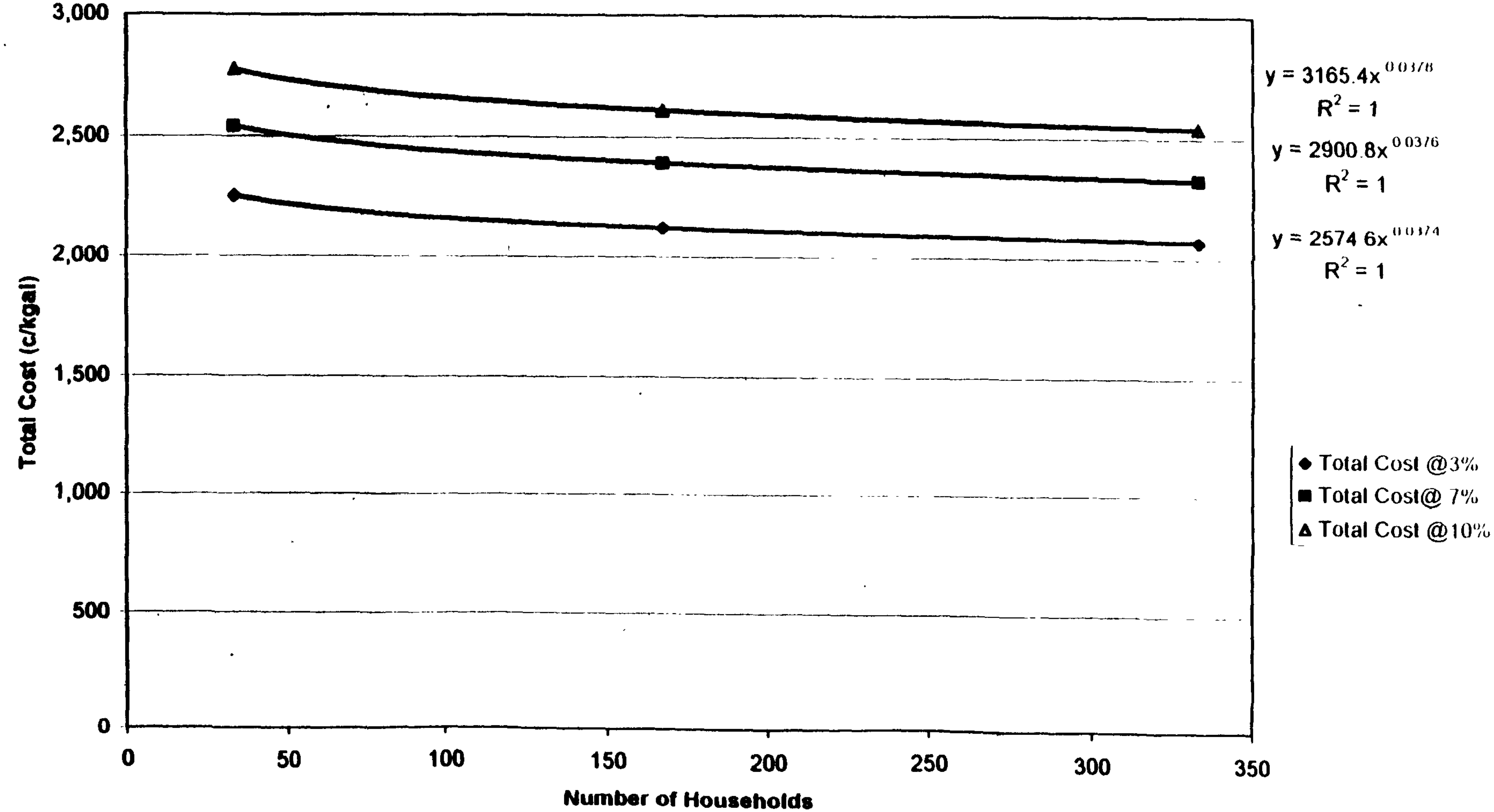


Figure A-10
Total Cost Regression Analysis for
DBP Control in Ground Water
-POU Reverse Osmosis Devices-

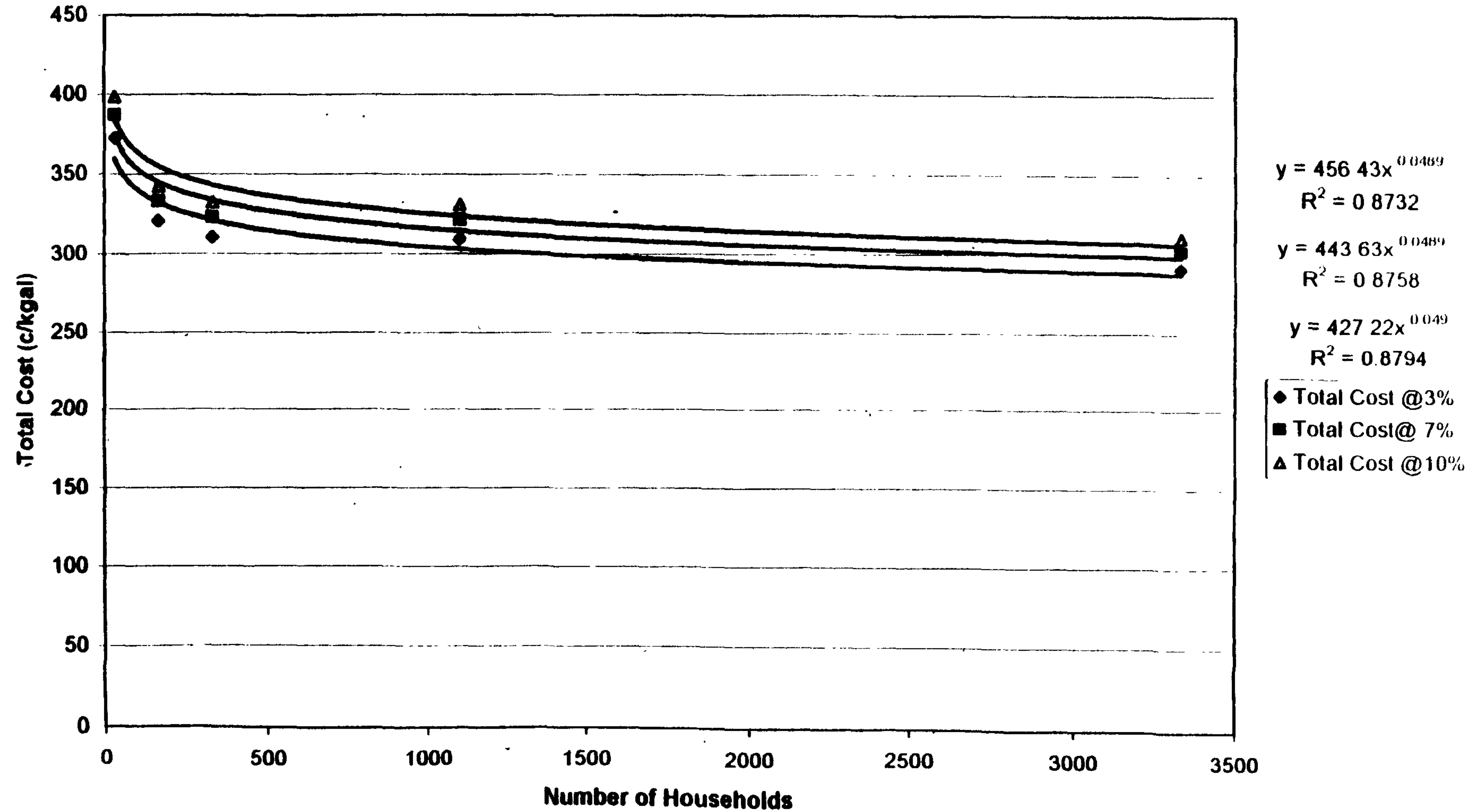


Figure A-11
Total Cost Regression Analysis for DBP Control in Ground Water
-POE GAC Devices-

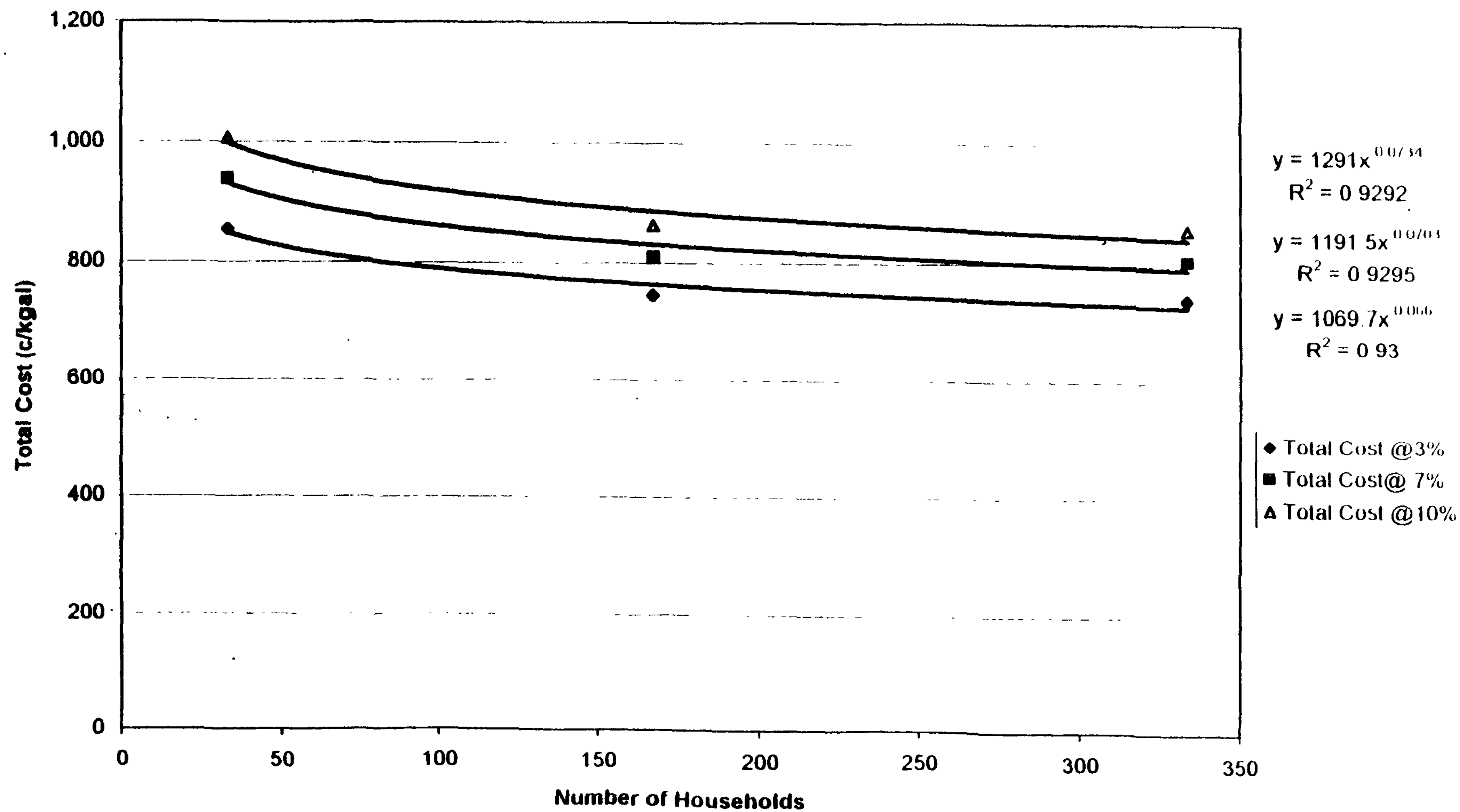


Figure A-12
Total Cost Regression Analysis for DBP Control in Ground Water
-POU GAC Devices-

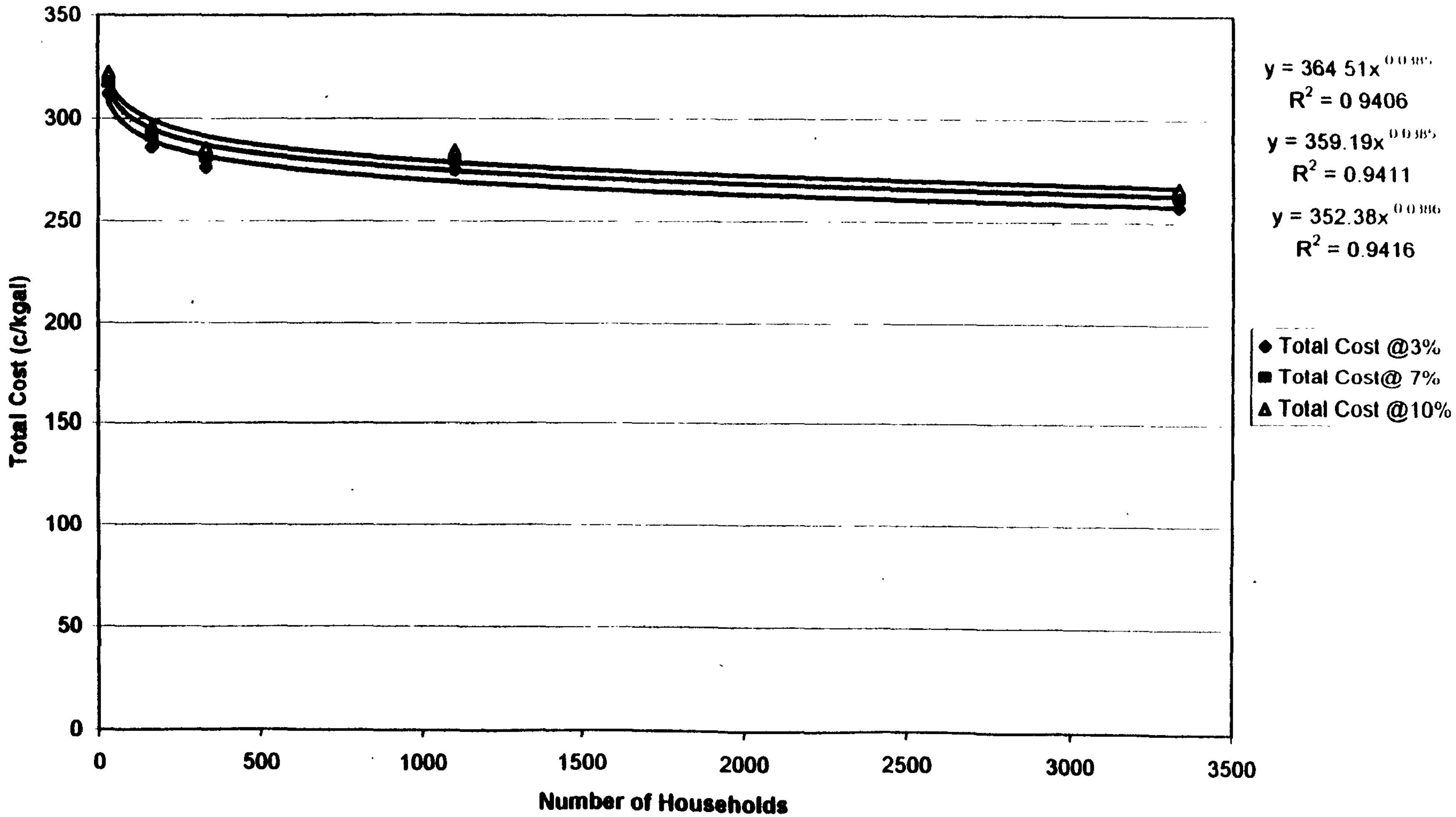


Figure A-13
Total Cost Regression Analysis for DBP Control in Surface Water
-POE Reverse Osmosis Devices-

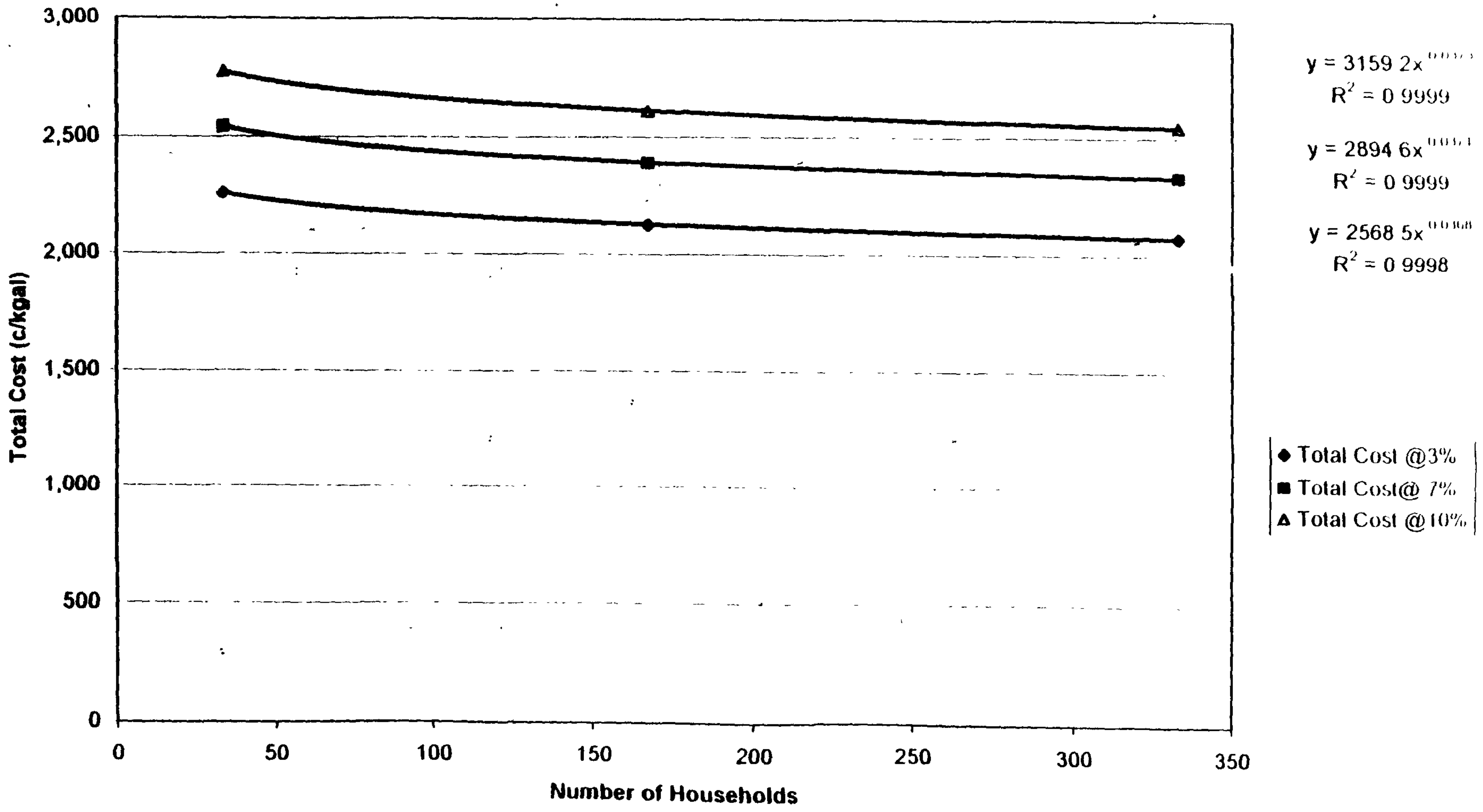


Figure A-14
Total Cost Regression Analysis for
DBP Control in Surface Water
-POU Reverse Osmosis Devices-

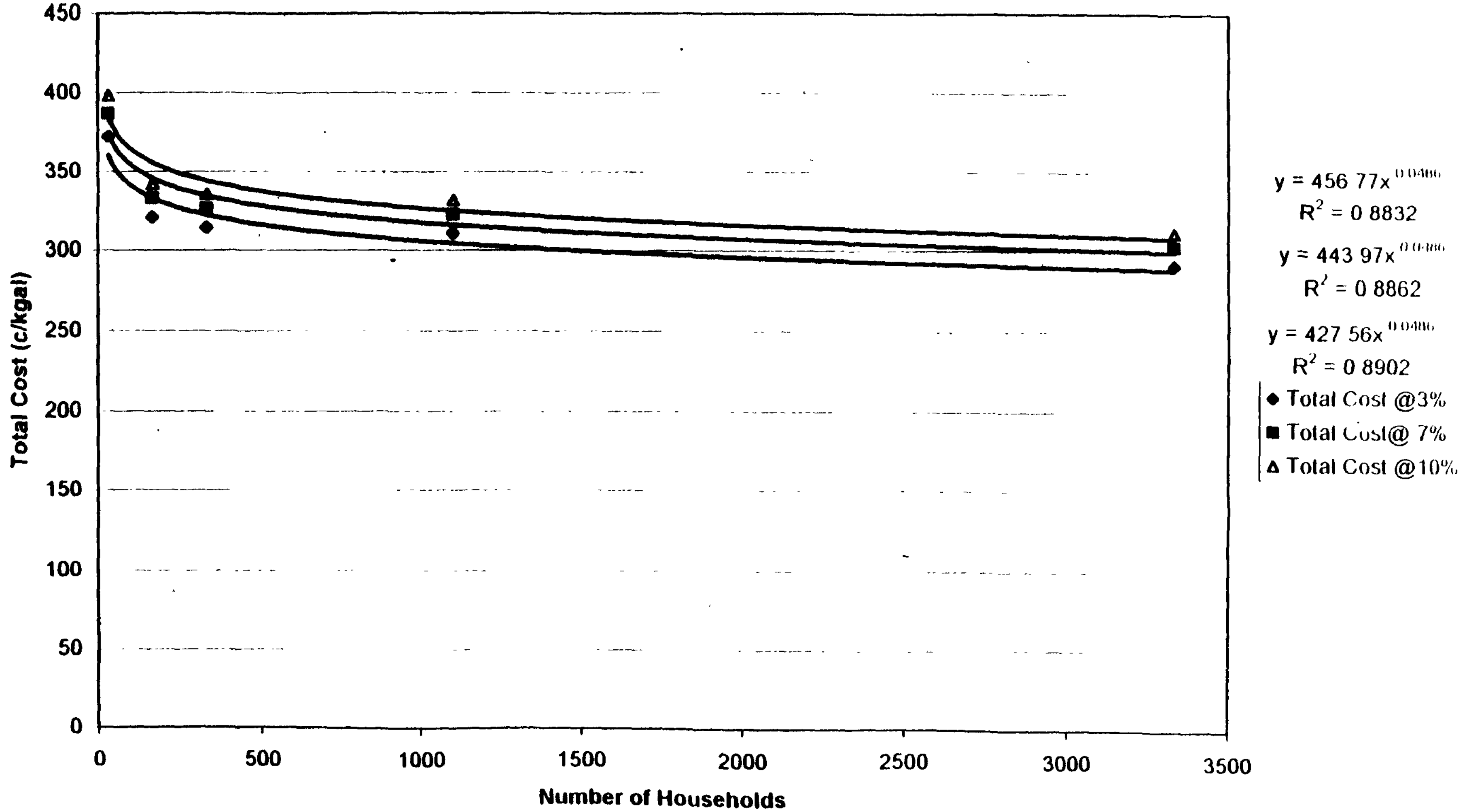


Figure A-15
Total Cost Regression Analysis for DBP Control in Surface Water
-POE GAC Devices-

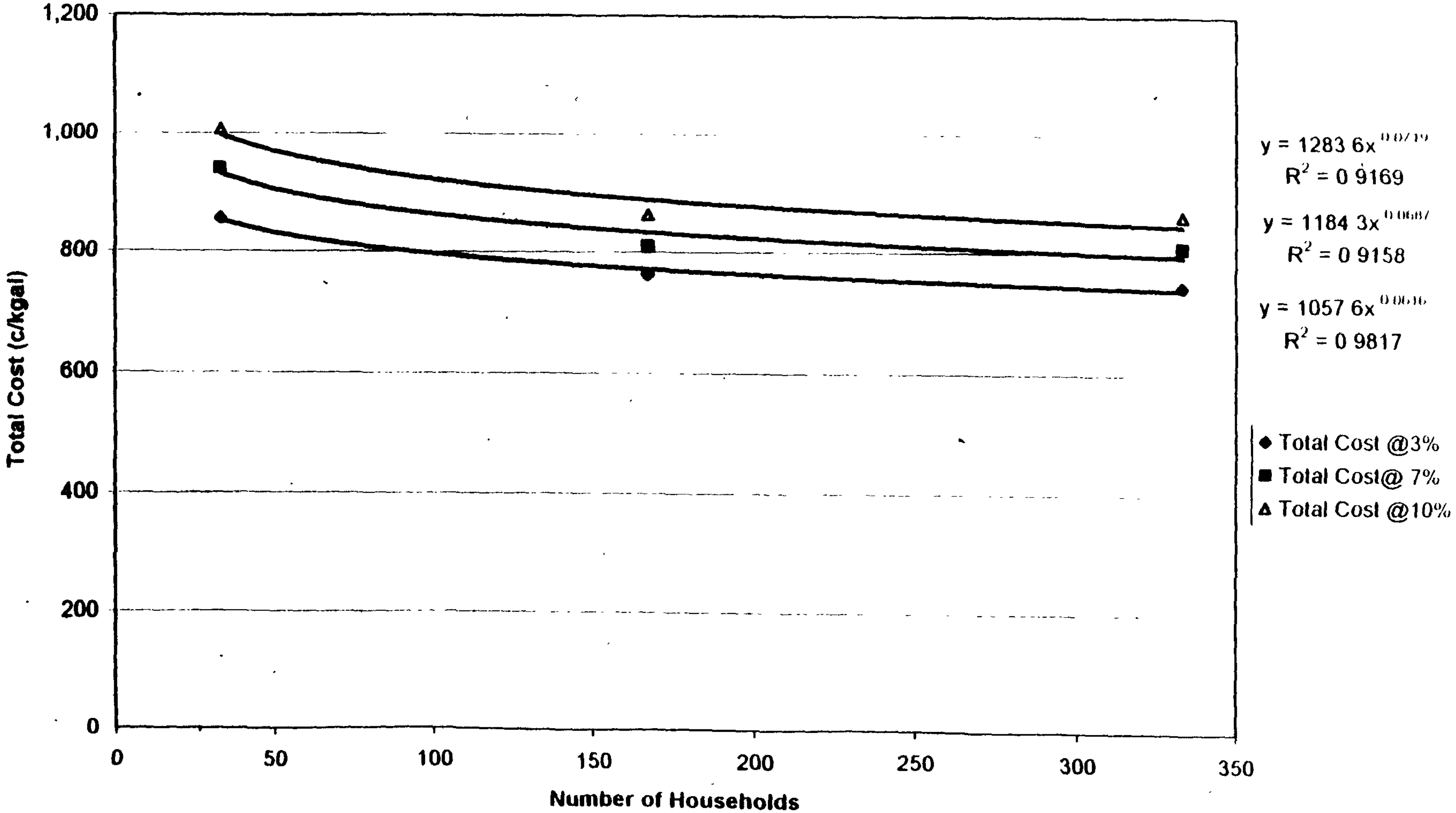
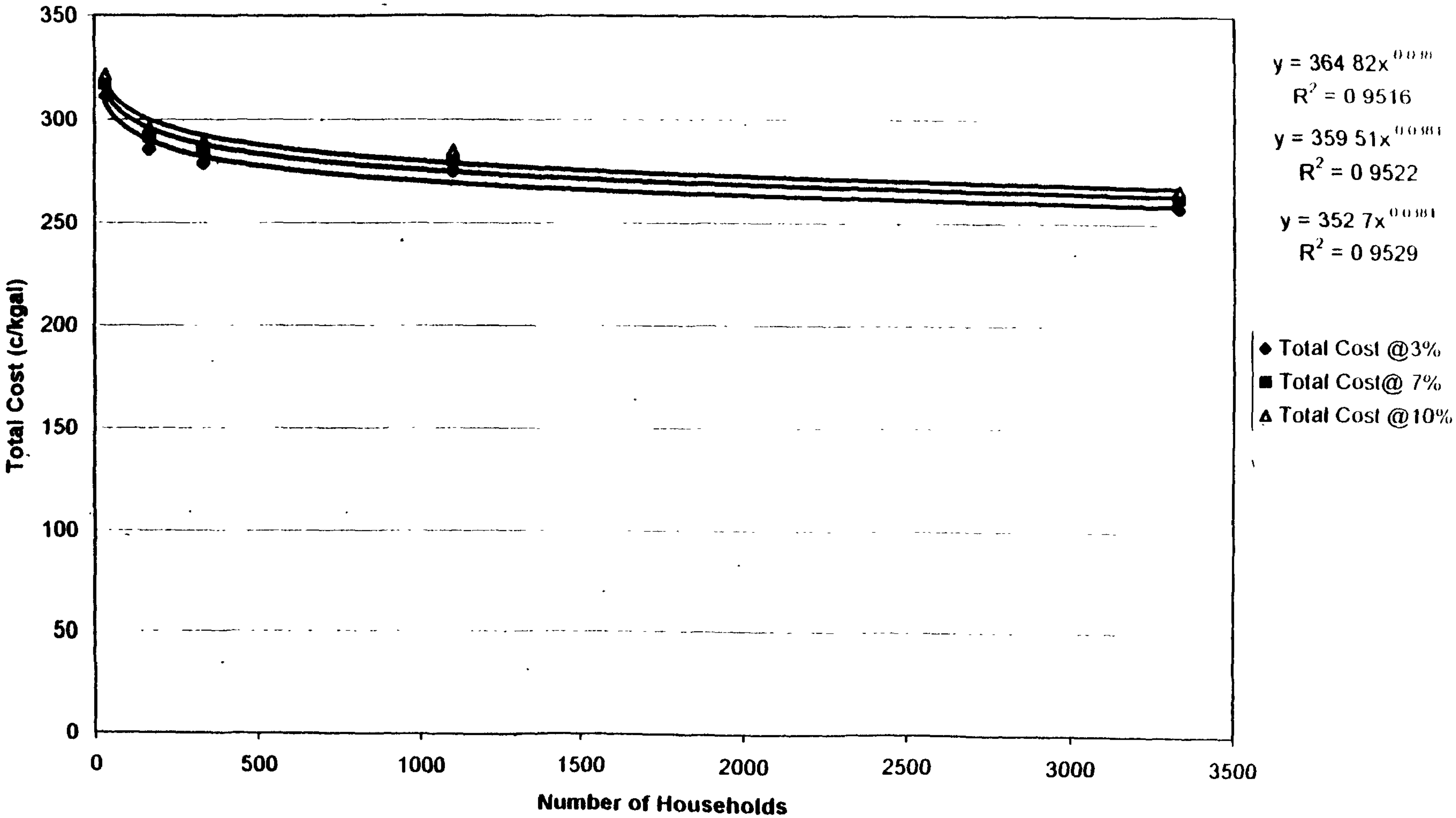
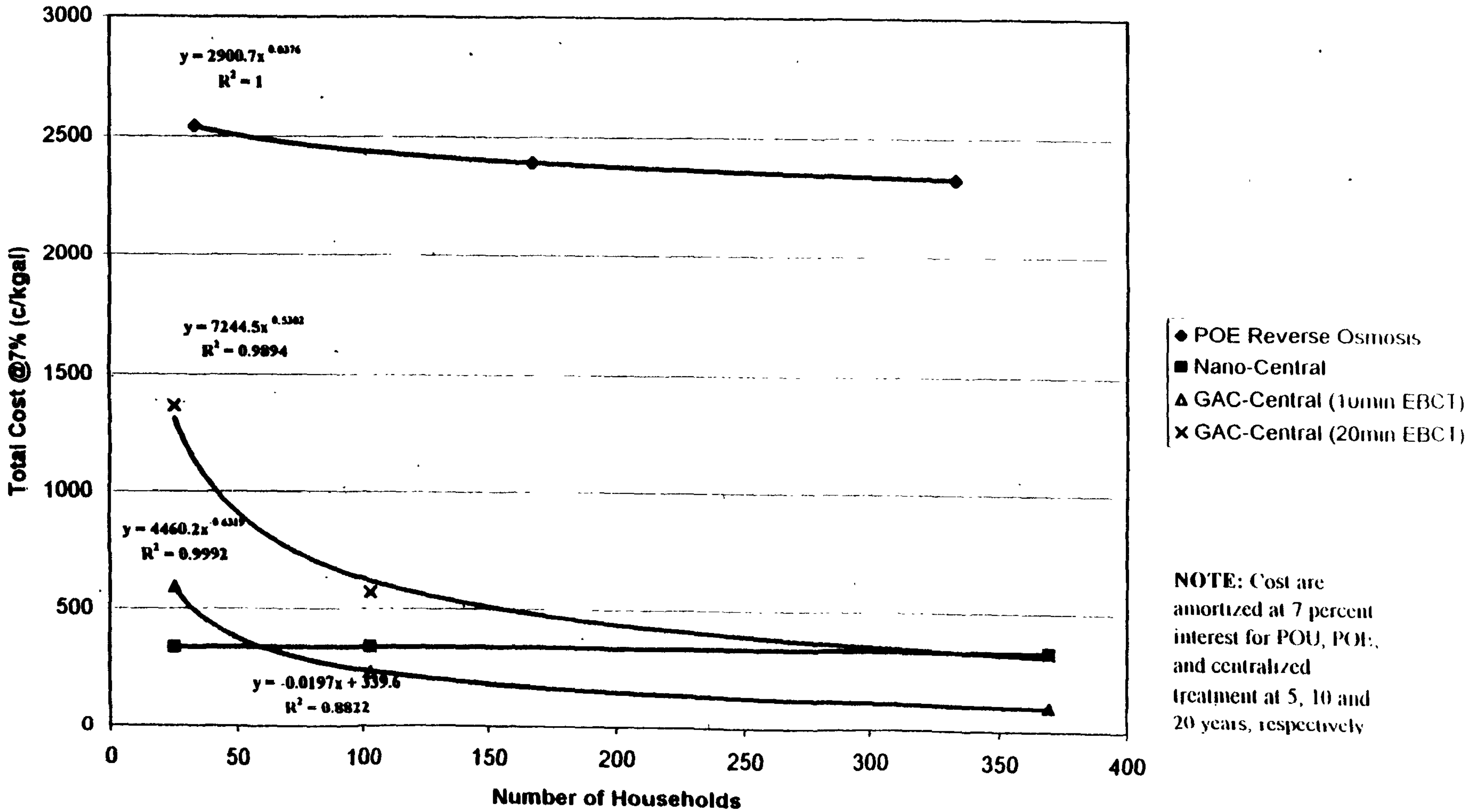


Figure A-16
Total Cost Regression Analysis for
DBP Control in Surface Water
-POU GAC Devices-



Appendix B

Figure B-1
Break-Point Analysis for
DBP Control Utilizing POE Reverse Osmosis (Ground Water)



NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-2
Break-Point Analysis for
DBP Control Utilizing POU Reverse Osmosis (Ground Water)

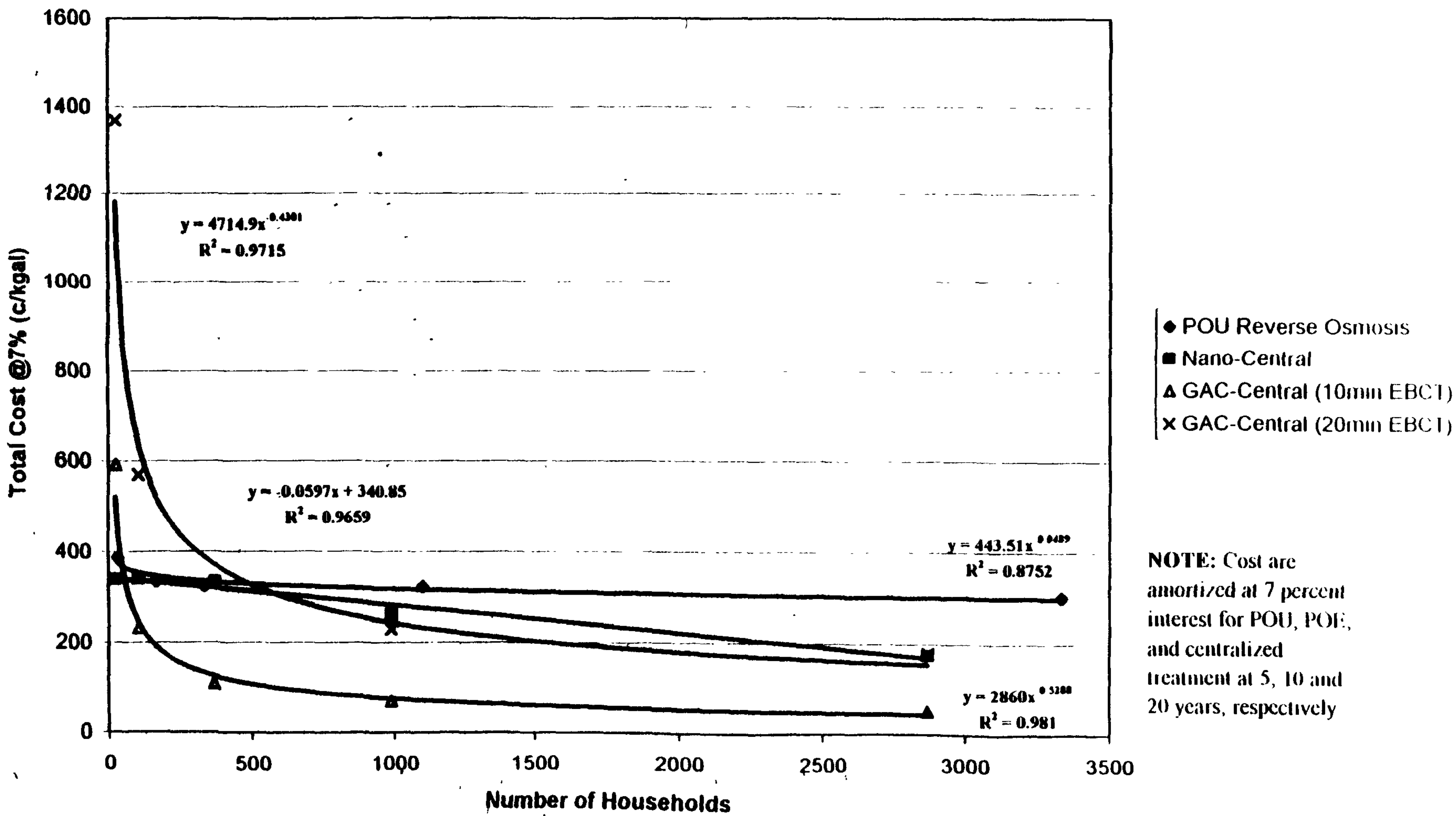
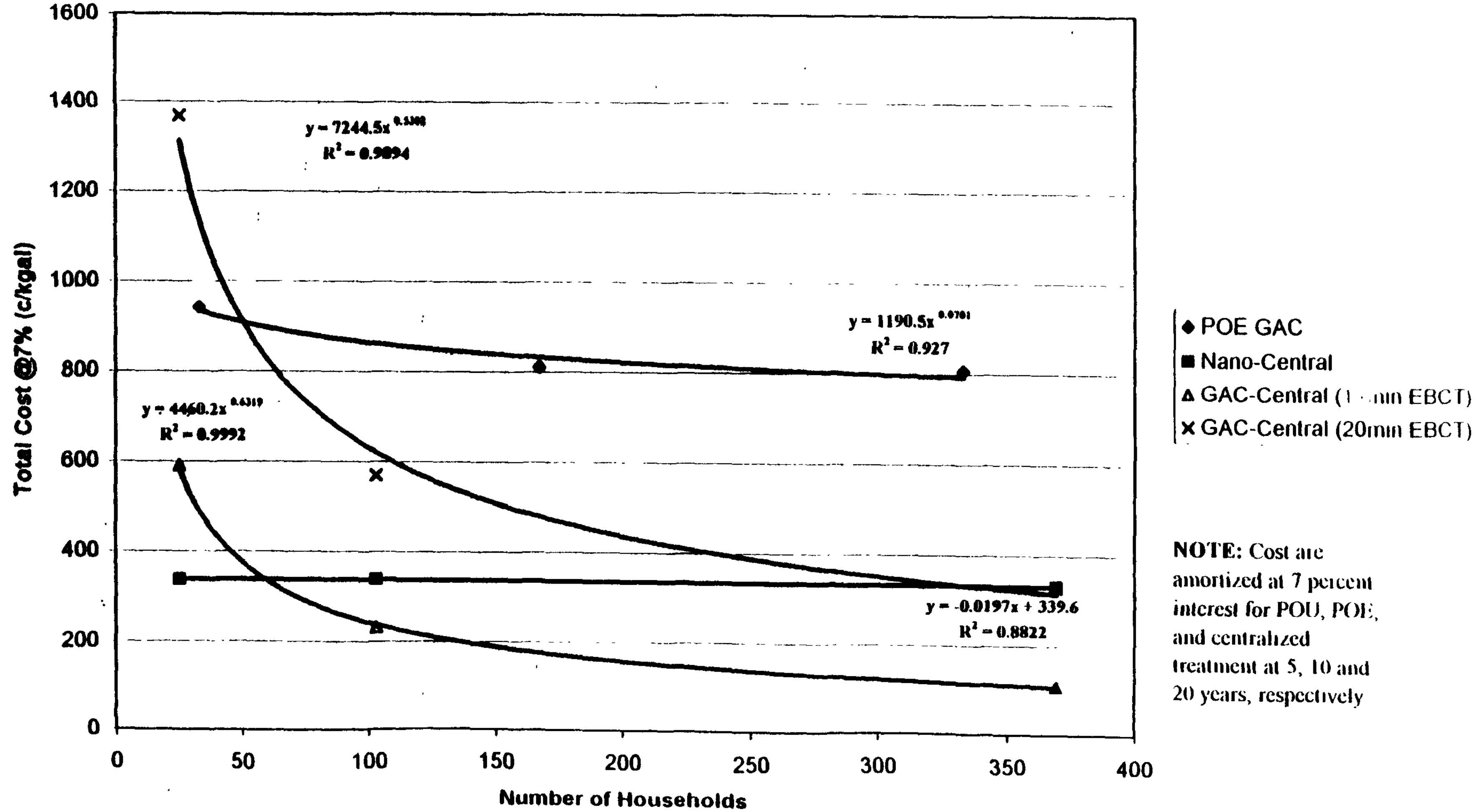
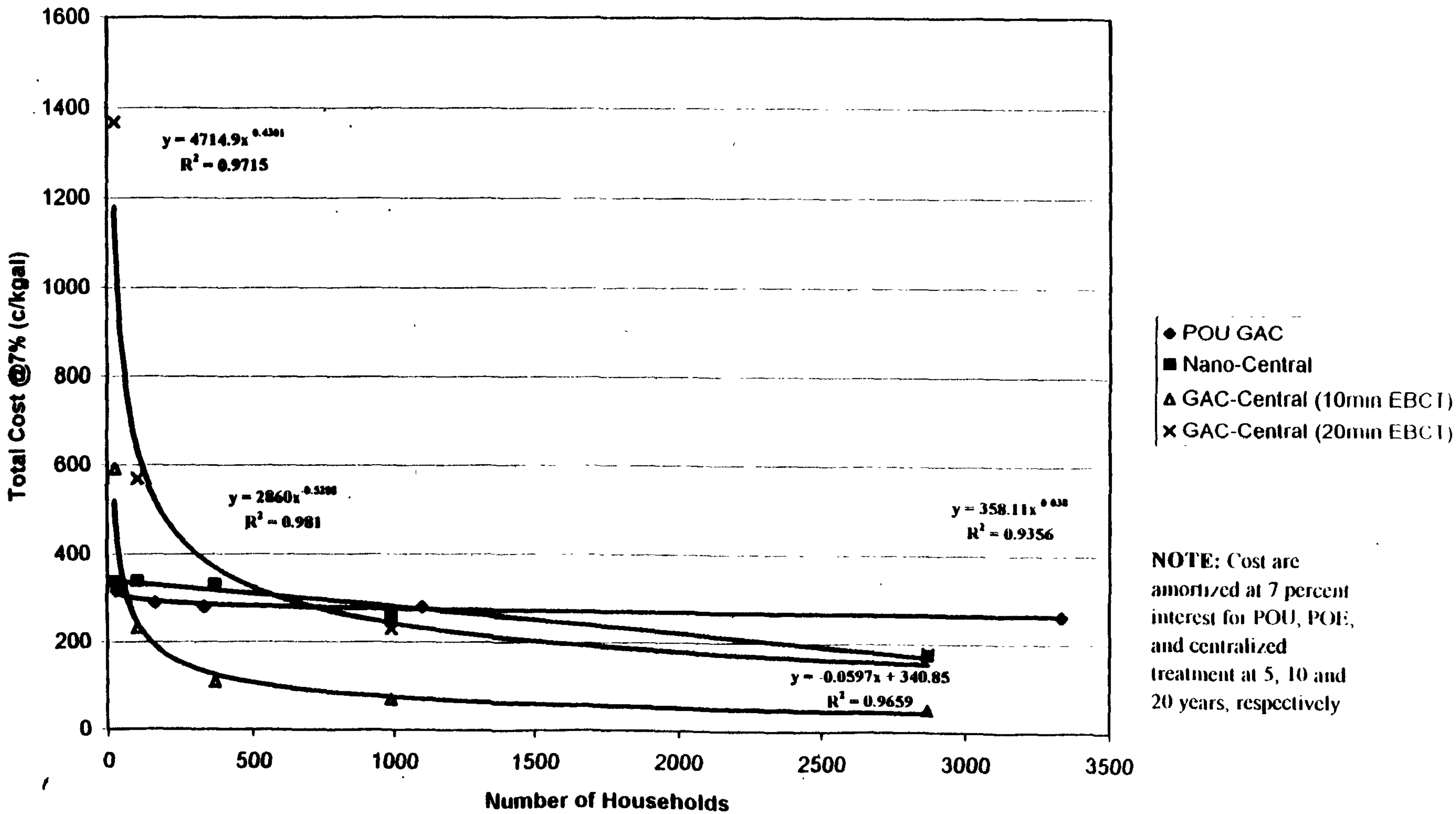


Figure B-3
Break-Point Analysis for
DBP Control Utilizing POE GAC (Ground Water)



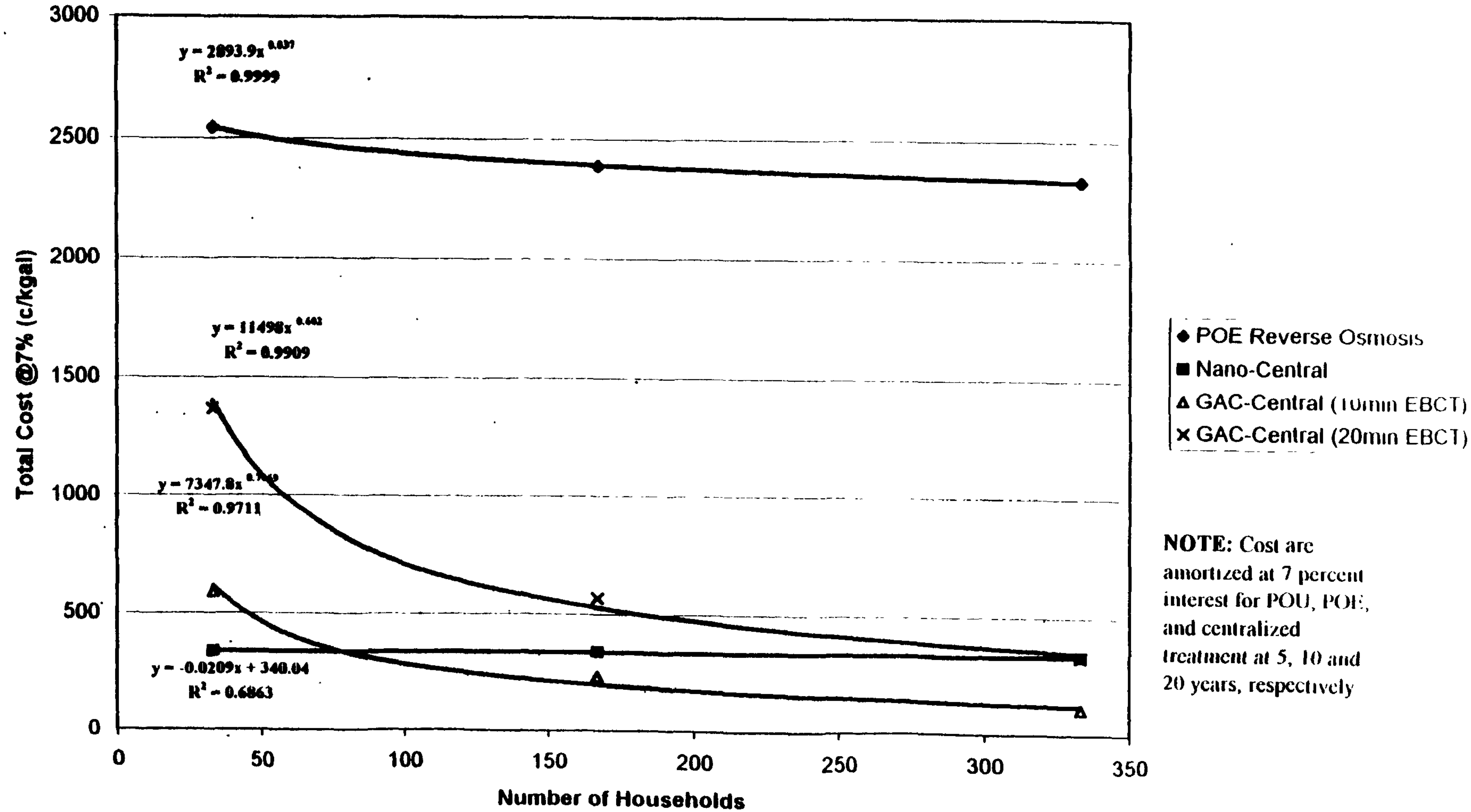
NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-4
Break-Point Analysis for
DBP Control Utilizing POU GAC (Ground Water)



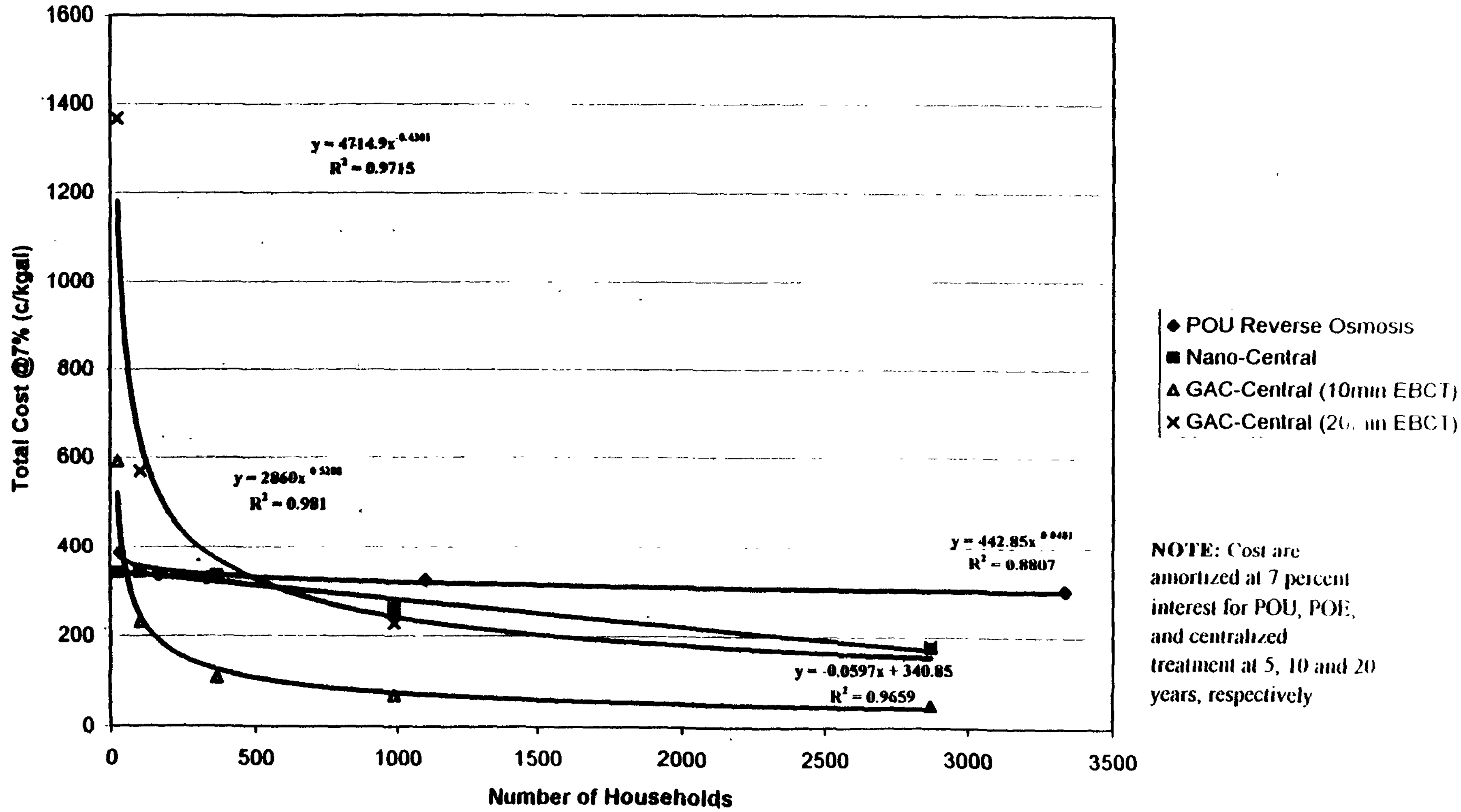
NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-5
Break-Point Analysis for
DBP Control Utilizing POE Reverse Osmosis (Surface Water)



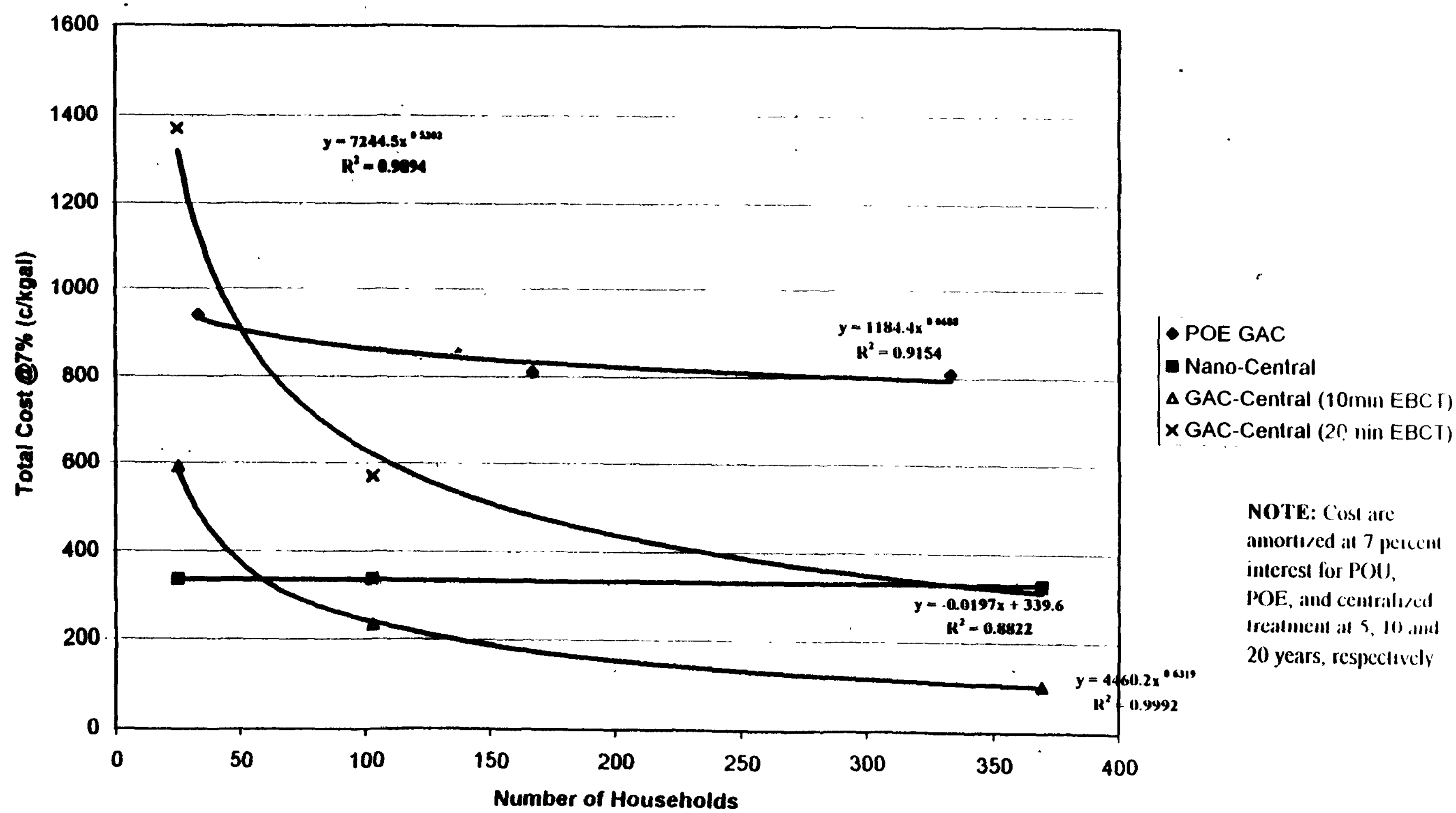
NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-6
Break-Point Analysis for
DBP Control Utilizing POU Reverse Osmosis (Surface Water)



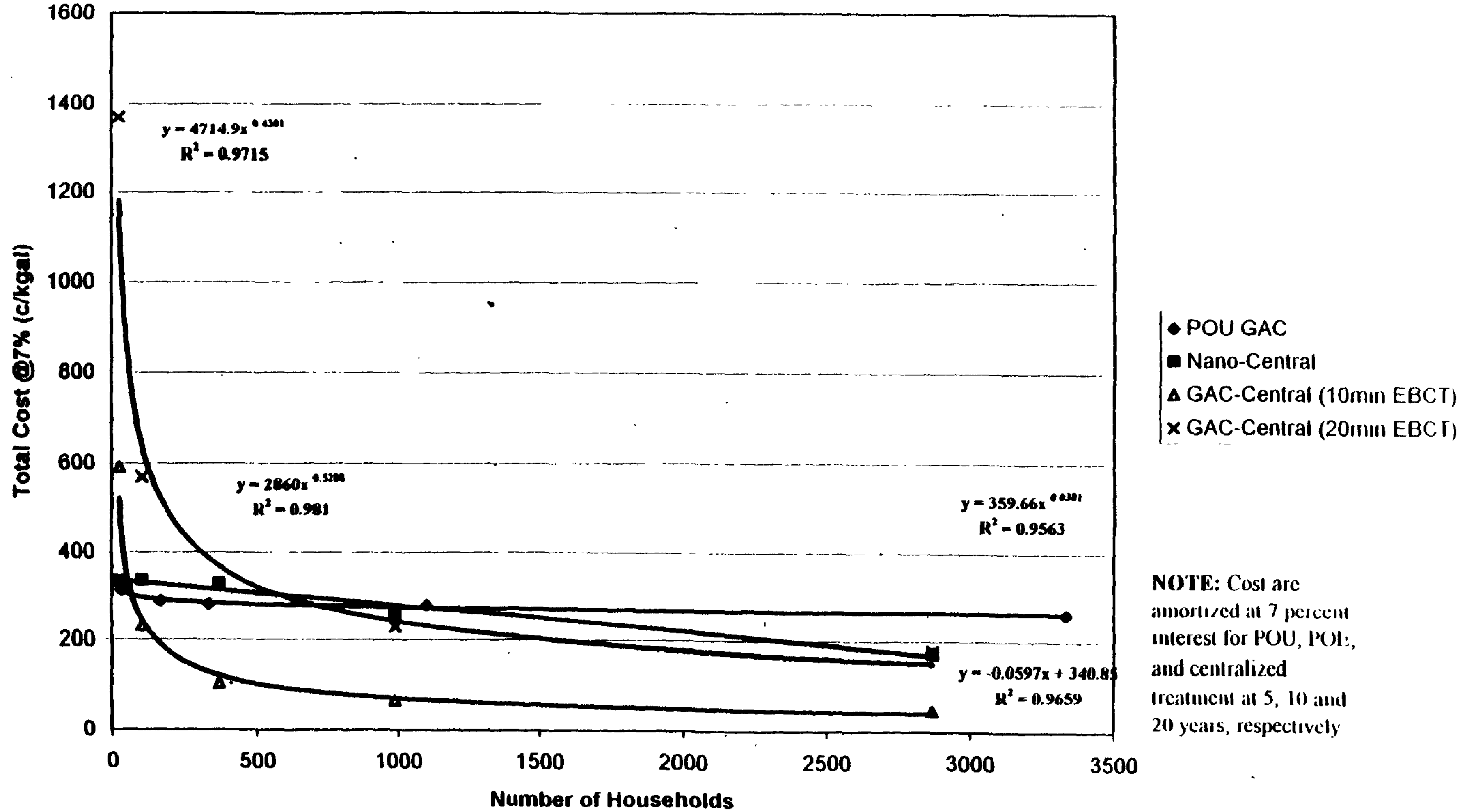
NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-7
Break-Point Analysis for
DBP Control Utilizing POE GAC (Surface Water)



NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively

Figure B-8
Break-Point Analysis for
DBP Control Utilizing POU GAC (Surface Water)



NOTE: Cost are amortized at 7 percent interest for POU, POE, and centralized treatment at 5, 10 and 20 years, respectively