CHAPTER 8

COST AND ENERGY REQUIREMENTS

8.1 INTRODUCTION

Costs associated with wastewater treatment facilities fall under one of two categories: capital costs and operations and maintenance (O&M) costs. The price of energy makes up a significant portion of O&M costs for most wastewater treatment facilities. Although O&M cost data for many of the pond types and polishing methods are relatively limited, it is understood that these costs are generally lower than for conventional systems. Data presented in the following sections vary widely, but are thought to be reasonable estimates to serve as guides in budgeting for the costs associated with a treatment system. It should be kept in mind, however, that the data have different constraints that may be applicable to a specific design. Conventional estimating procedures should be used during final design.

8.2 CAPITAL COSTS

Construction cost data presented in this section were extracted from EPA reports (U. S. EPA, 1980c; U.S. EPA, 1999, 2000a, 2006) and bid Summary Sheets provided by the various EPA regions (R8: Brobst, 2007; R5: Martin, 2007; R9: McNaughton, 2007; Oklahoma: Rajaraman, 2007). The costs extracted from the EPA report (1980c) were indexed to Kansas City/St. Joseph, Missouri during the fourth quarter of 1978. These data were projected for Kansas City to 2006 and the bid sheets corrected to Kansas City as a baseline using the ENR CC Indices (www.enr.com), which are available by subscription. General information about construction costs is available in Fact Sheet 5: Treatment Series, Lagoons, Performance and Cost of Decentralized Unit Processes (werf.org/AM/Template). To compare costs of ponds with other types of treatment, it is suggested that the engineer consult relevant references for her/his region.

Construction costs only are represented in Figures 8-1 through 8-4. Associated costs include administration/legal, preliminary, land, structures, right-of-way, mobilization, architect/engineer (A/E) basic fees, other A/E fees, project inspection costs, land development, relocation, demolition and removal, bond interest, indirect costs, miscellaneous, equipment, and contingencies. These represent approximately 50 percent of the construction costs.

Figure 8-1 contains both the 1978 corrected data and the data from the bid summary sheets for flow through ponds (facultative). Figure 8-2 contains data extracted from the low bid on the bid summary sheets for flow through ponds. Predicted construction costs using the equations of best fit from Figure 8-1 and 8-2 result in similar estimates, but the estimates deviate considerably from individual construction cost values.

The low flow rates presented in the bid summary sheet data are lumped together with several other data points that does not seem to influence the fit of the data. With one exception, the R^2 of the bid summary sheet data is = 0.705, a relatively good fit. Therefore, with low-flow systems, it is probably prudent to use the bid sheet projection equations with the best coefficient of determination (R^2) to estimate the cost of a flow-through pond.

Insufficient data were available for the non-discharging and aerated ponds, therefore they could not be compared to the bid summary sheet data combined with the updated Kansas City data. The data points from the bid sheets agreed reasonably well with the up dated information.

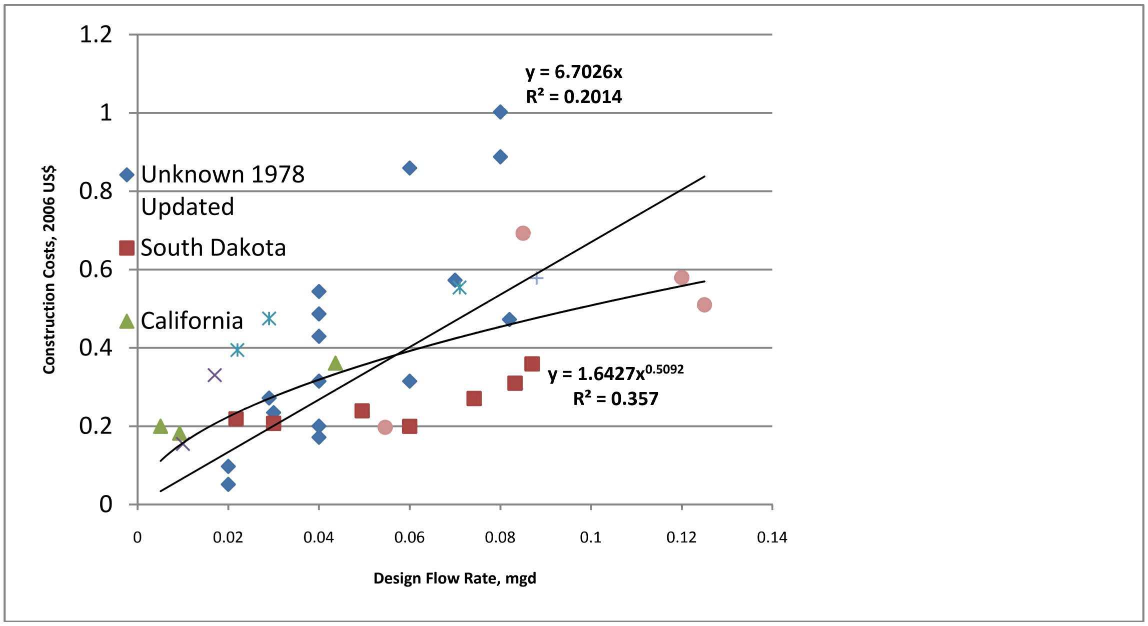


Figure 8-1. Construction costs vs. DFR for flow-through ponds (facultative), Kansas City, 2006. (DFR < 500,000 L/d [0.130 MGD]) . See p. xiv for conversion table.

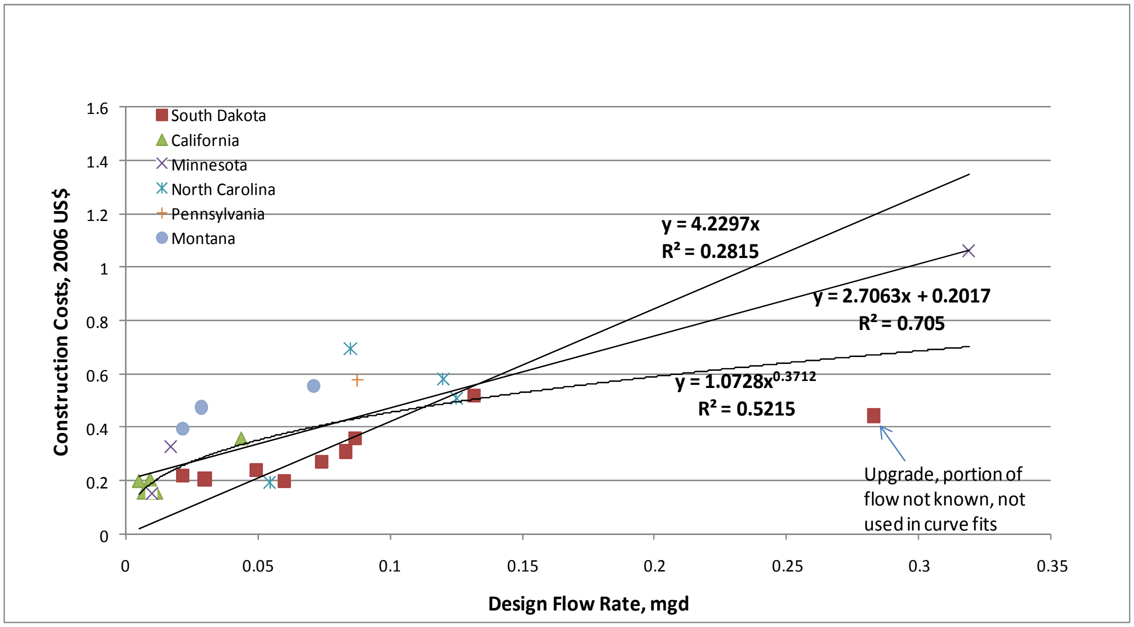


Figure 8-2. Data bid tabulations: construction costs vs. DFR for flow-through ponds, Kansas City, 2006.

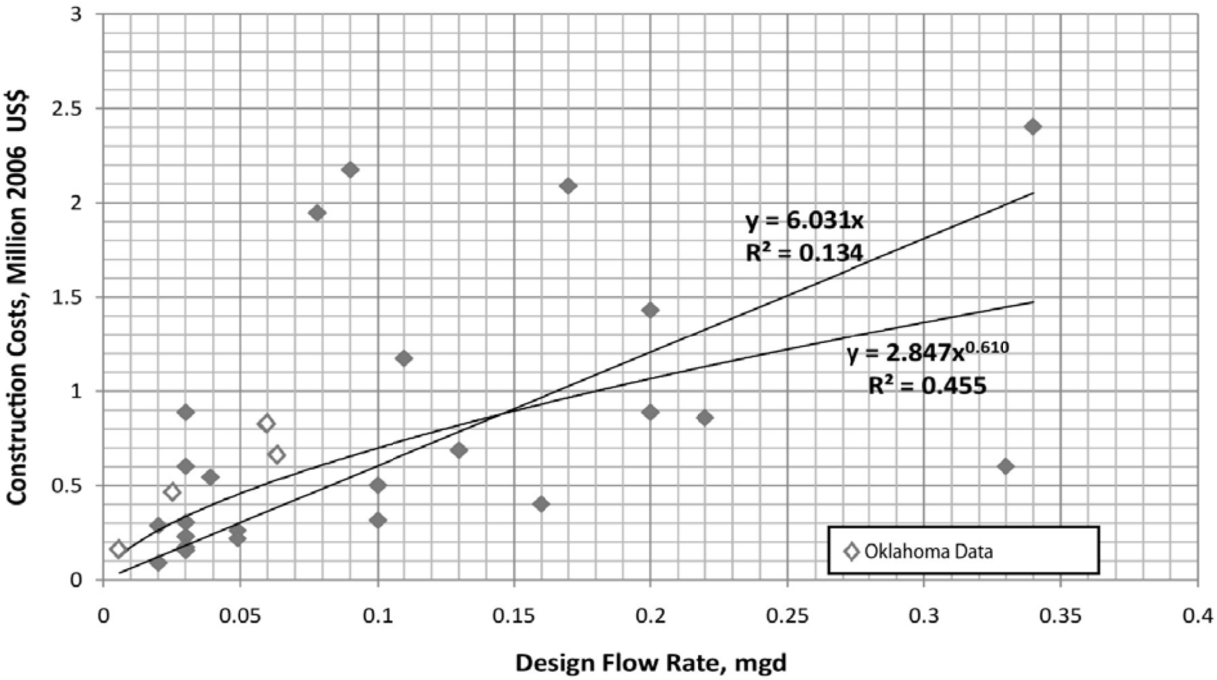


Figure 8-3. Construction costs vs. DFR for nondischarging ponds, Kansas City, 2006.

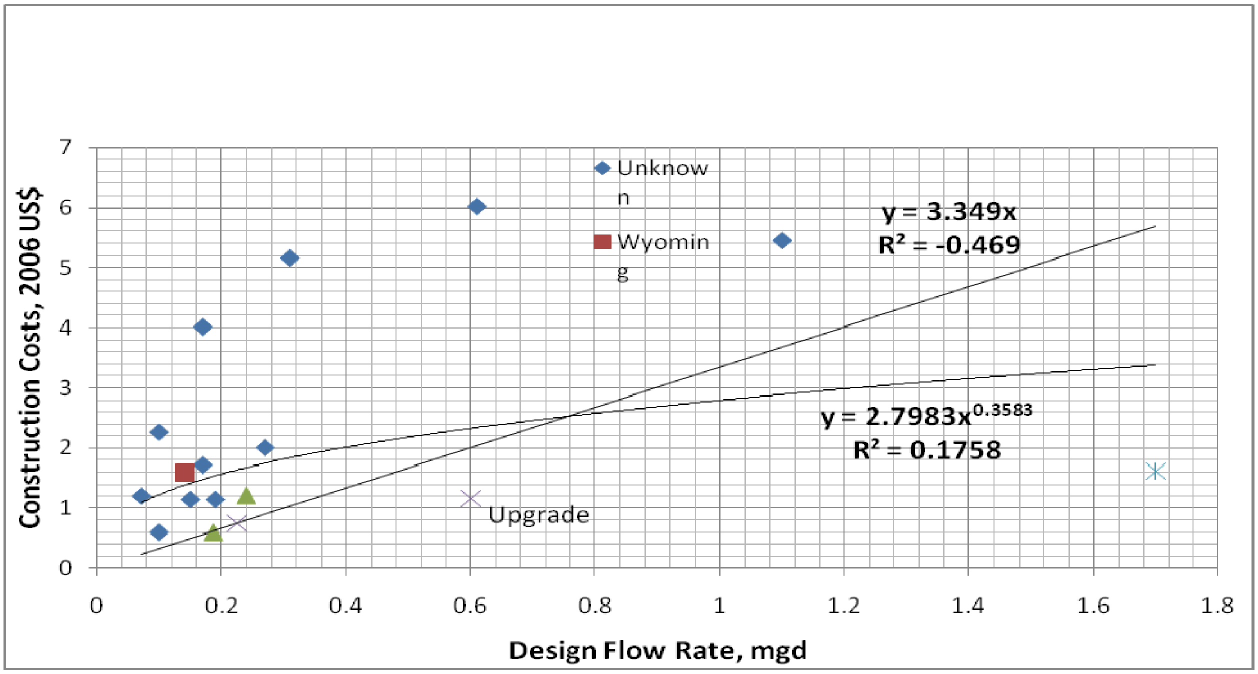


Figure 8-4. Construction costs vs. DFR for aerated ponds, Kansas City, 2006 - Q = 0 to 1.2 MGD.

8.3 UPDATING COSTS

Costs may be up dated to other cities by using the ratio of the 2006 ENR CC Index for Kansas City to the ENR CC index for the location of interest as shown in the following equation:

$$\text{Updated Construction Costs} = \frac{\text{ENR CC Index for City of Choice}}{\text{ENRCC Index for Kansas City (12/2006)}}$$

8.4 COST DATA FOR UPGRADING METHODS

There are many options for the upgrading of pond systems, but accurate cost data for all of the systems are not available. Wetlands, land application, granular media filtration, dissolved air flotation, and sequencing batch reactors cost data are relatively expensive as is shown in the following sections. Data for rock filters, intermittent sand filters, fish production, hyacinth systems and other plant applications are limited. General cost estimation techniques are presented for the systems with limited data.

8.4.1 Wetlands

8.4.1.1 Free Water Surface Wetlands (FWS) Cost Estimation

The available cost data for FWS constructed wetlands are difficult to interpret given the number of design constraints placed on the various systems. The size required and resulting costs will vary depending upon whether the systems are designed to remove BOD_5, TSS, NH_3 or total N.

Further information about costs for FWS constructed wetlands can be found in U.S. EPA, (2000b) and Crites et al. (2006).

8.4.1.2 Subsurface Flow (SSF)

Available cost data for SSF constructed wetlands are hard to interpret because of design constraints that may be placed on the particular system. It is not clear what the design parameters were for most of the systems. Further information about costs for SSF wetlands can be obtained in U.S. EPA (2000b) and Crites et al. (2006).

8.4.2 Land Application Cost Estimation

A detailed discussion of the various types of land application treatment of wastewaters can be found in U.S. EPA (2006), Shilton (2005) and Crites et al. (2006). There are three basic land application methods: slow rate, overland flow, and soil aquifer treatment or rapid infiltration. Capital costs and labor costs were compiled in U.S. EPA 2006 for an ENR CCI of 6076. Construction costs and labor, materials and energy costs for center pivot irrigation, solid set irrigation, gated pipe overland flow and rapid infiltration are shown in Figures 8-5 through 8-8. Land application systems should only be designed by an engineer who has first-hand experience or has studied the above references.

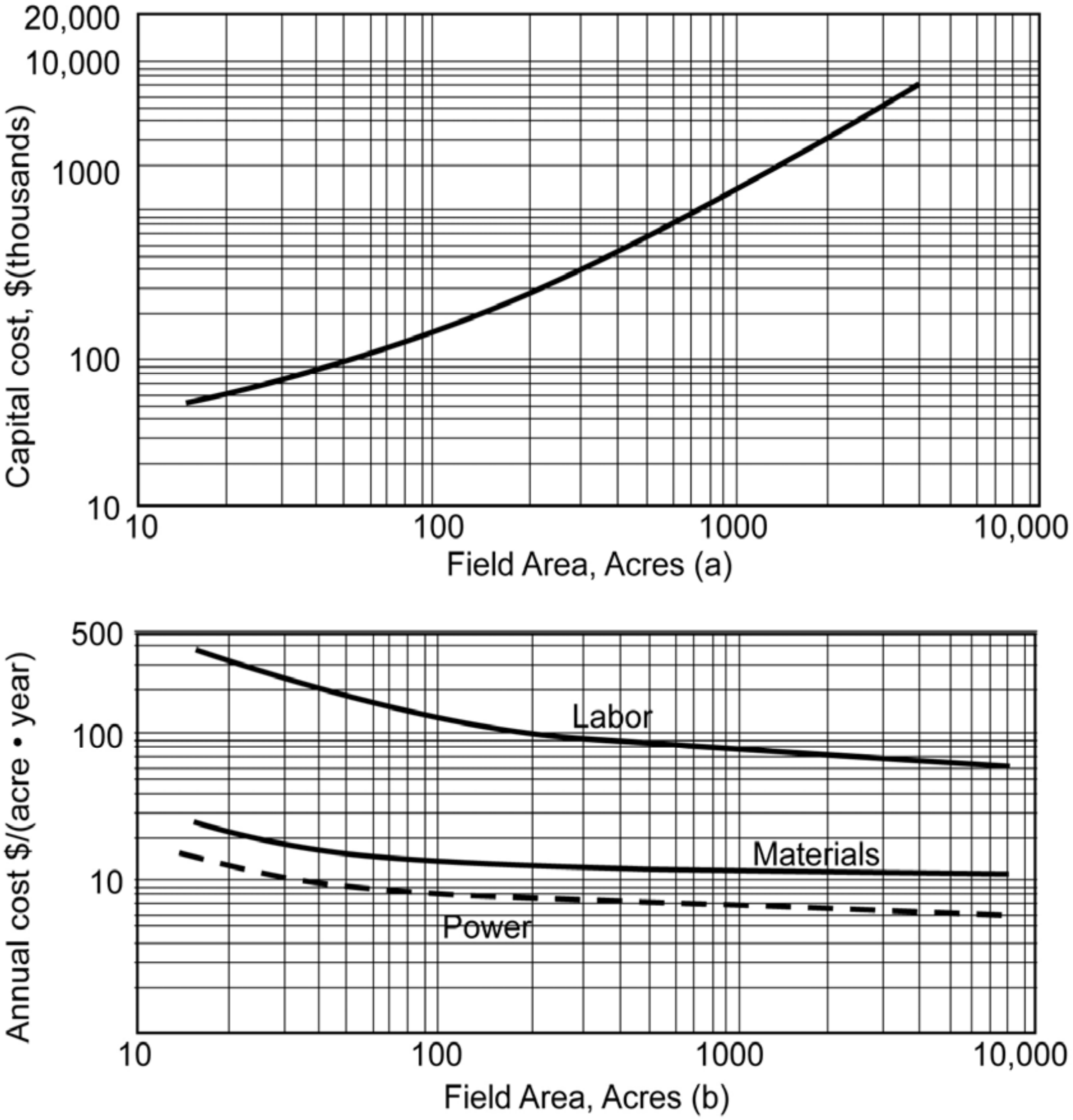


Figure 8-5. Center pivot sprinkling costs, ENR CCI = 6076: (A) capital cost; (B) operation and maintenance cost (U.S. EPA, 2006).

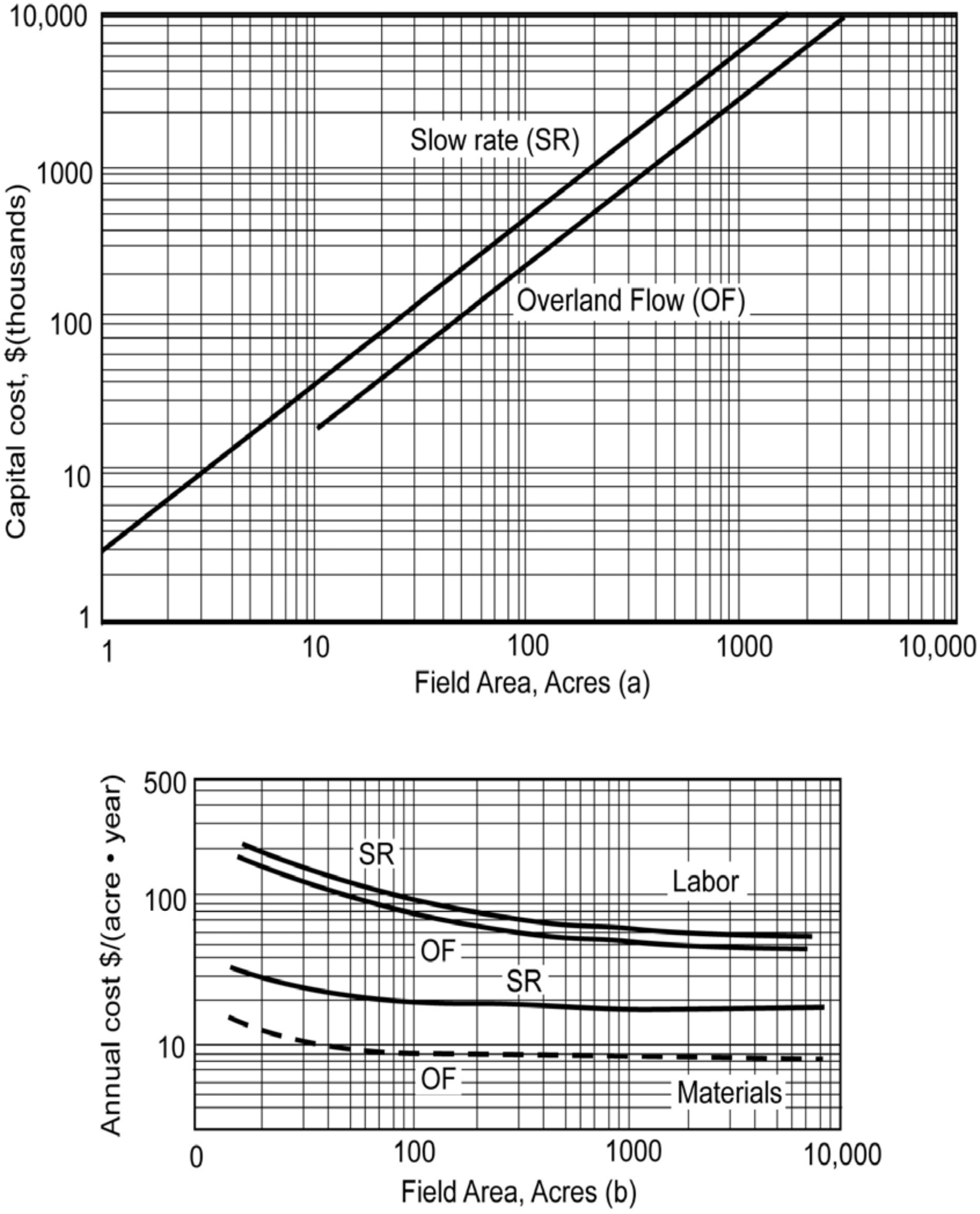
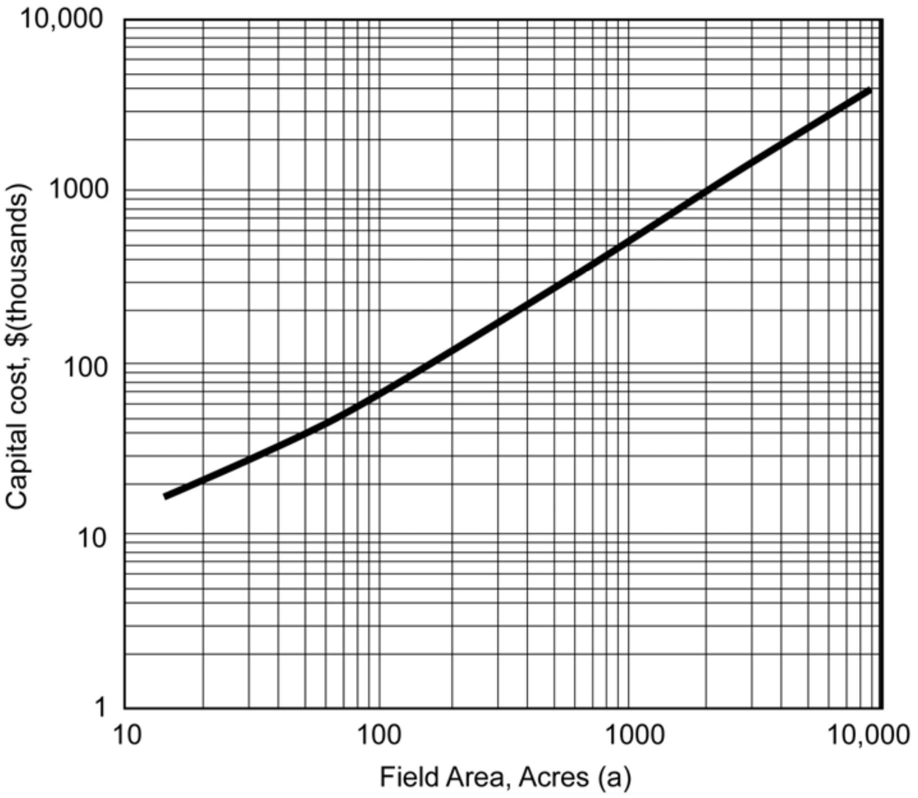


Figure 8-6. Solid set sprinkling (buried) costs, ENR CCI = 6076: (A) capital cost; (B) operation and maintenance cost (U.S. EPA, 2006).



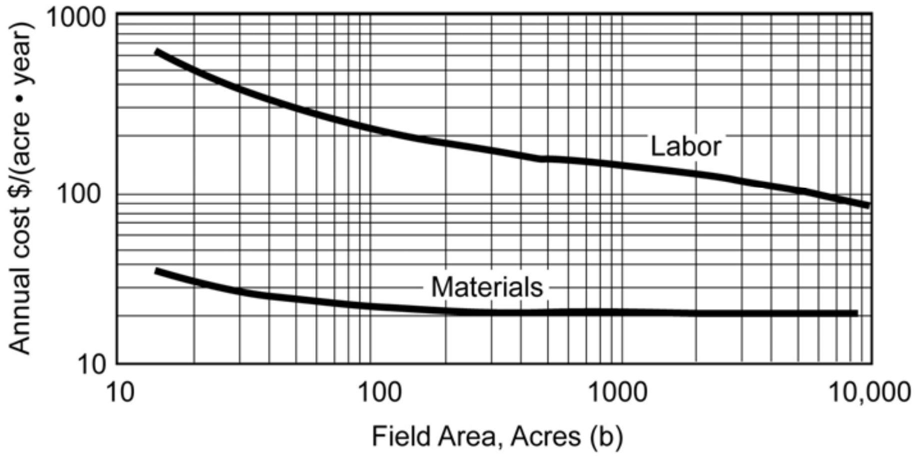


Figure 8-7. Gated pipe – overland flow or ridge-and-furrow slow rate costs, ENR CCI = 6076: (A) capital cost; (B) operation and maintenance cost (U.S. EPA, 2006).

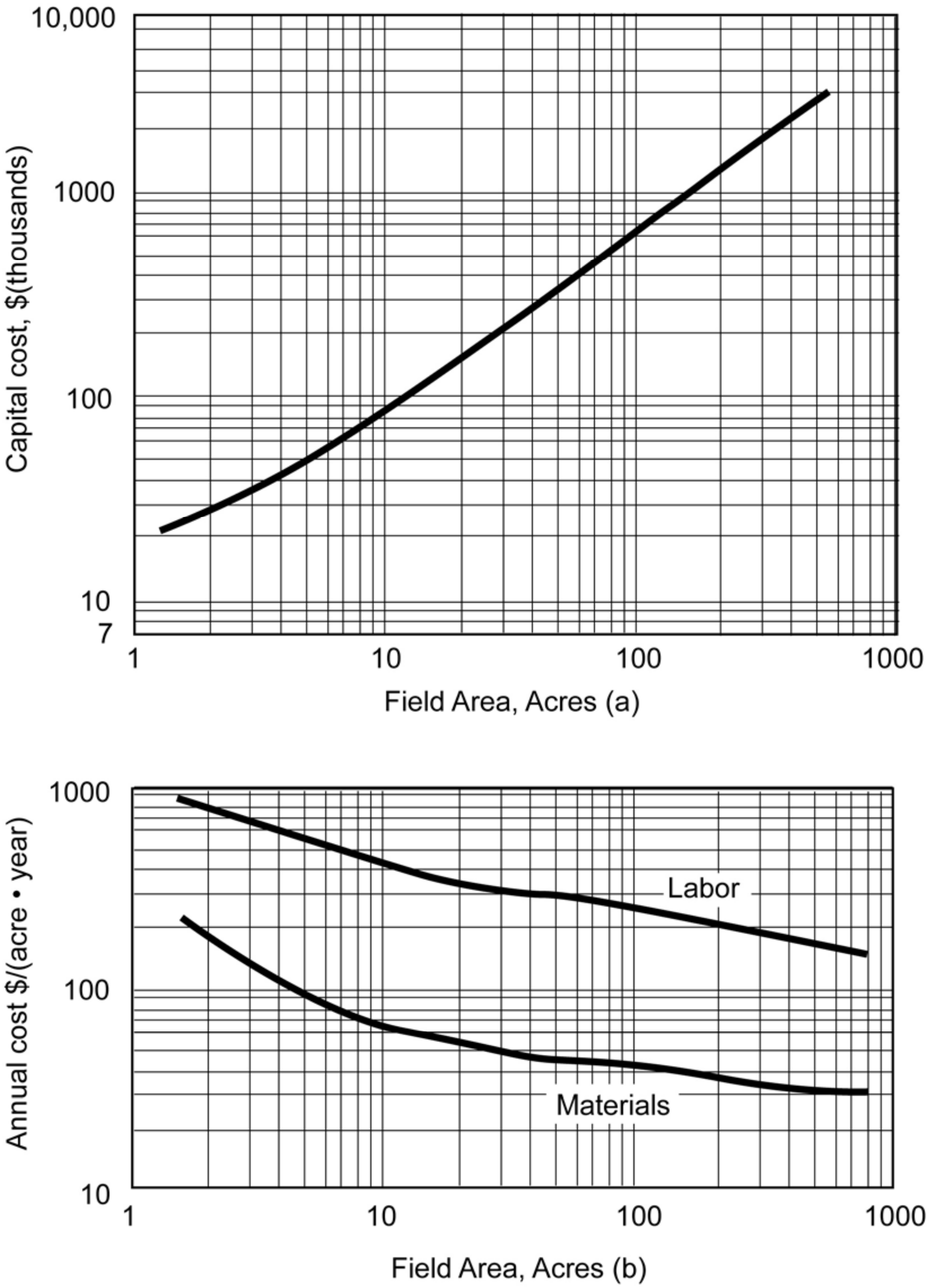


Figure 8-8. Rapid infiltration basin costs, ENR CCI = 6076.: (a) capital cost; (b) operation and maintenance cost (U.S. EPA, 2006).

8.4.3 Granular Media Filtration Cost Estimation

The relationships shown in Figures 8-9 and 8-10 were taken from the U.S. EPA (2000a) concerning the Centralized Waste Treatment (CWT) point source category. The data may not be totally accurate for pond systems, but are reasonable enough to provide guidance with regard to preliminary designs.

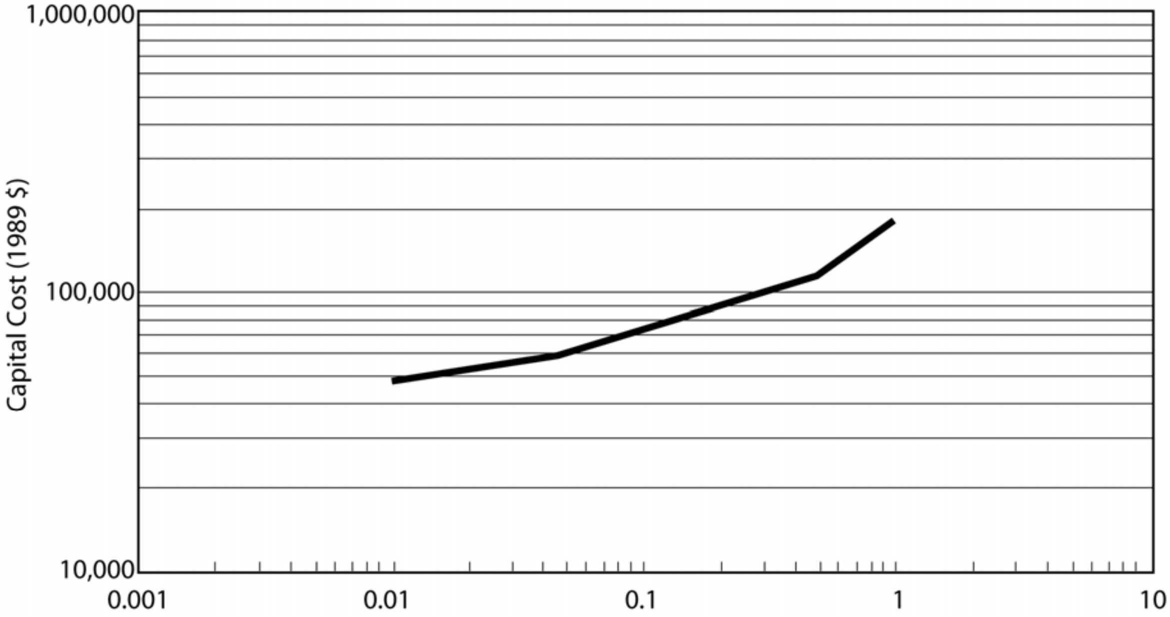


Figure 8-9. Mixed-media filtration capital costs, ENR CCI = 6076 (U.S. EPA, 2000a).

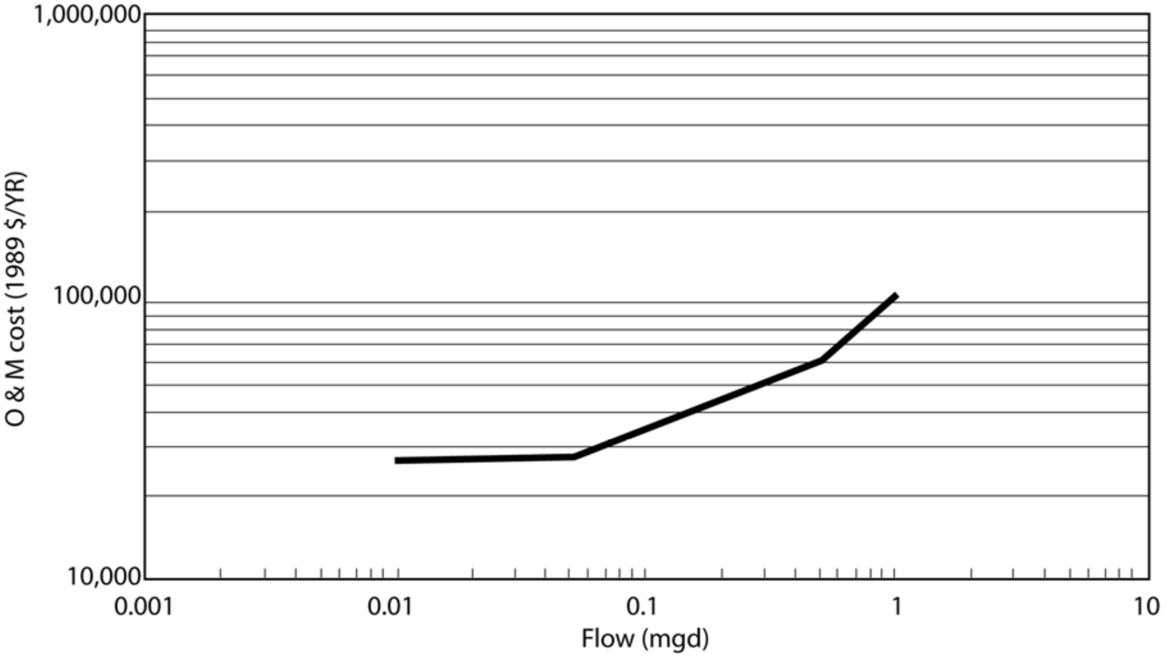


Figure 8-10. Mixed-media filtration O&M costs, ENR CCI = 6076 (U.S. EPA, 2000a).

8.4.4 Dissolved Air Flotation (DAF) Cost Estimation

The relationships shown in Figures 8-11 and 8-12 were taken from the U.S. EPA (2000a) concerning the CWT point source category. Again, the data may not be totally accurate for pond systems, but are reasonable enough to provide guidance with regard to preliminary design.

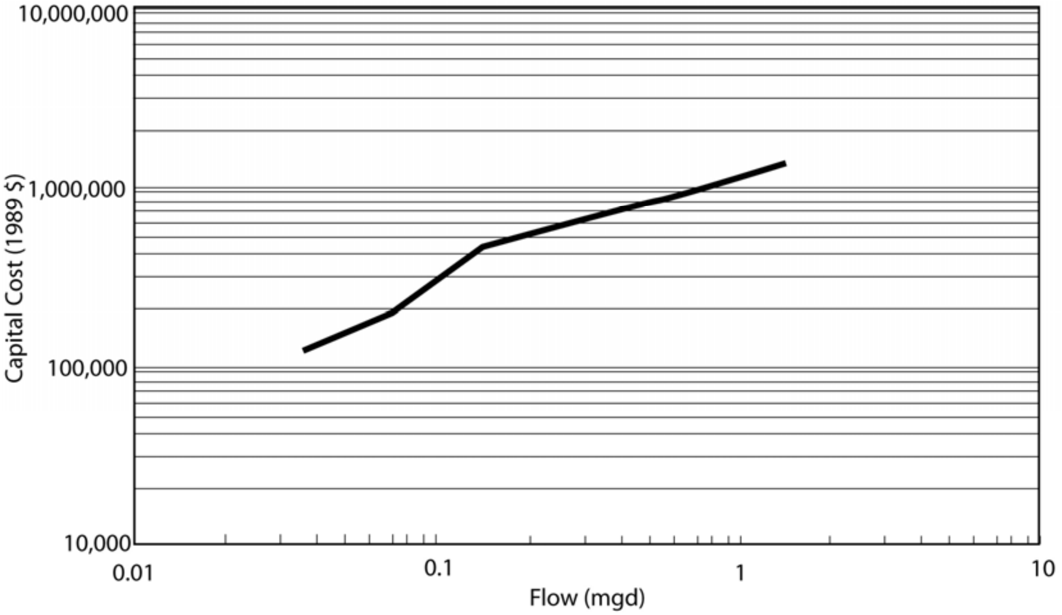


Figure 8-11. Dissolved air flotation capital costs, ENR CCI = 6076 (U.S. EPA, 2000a).

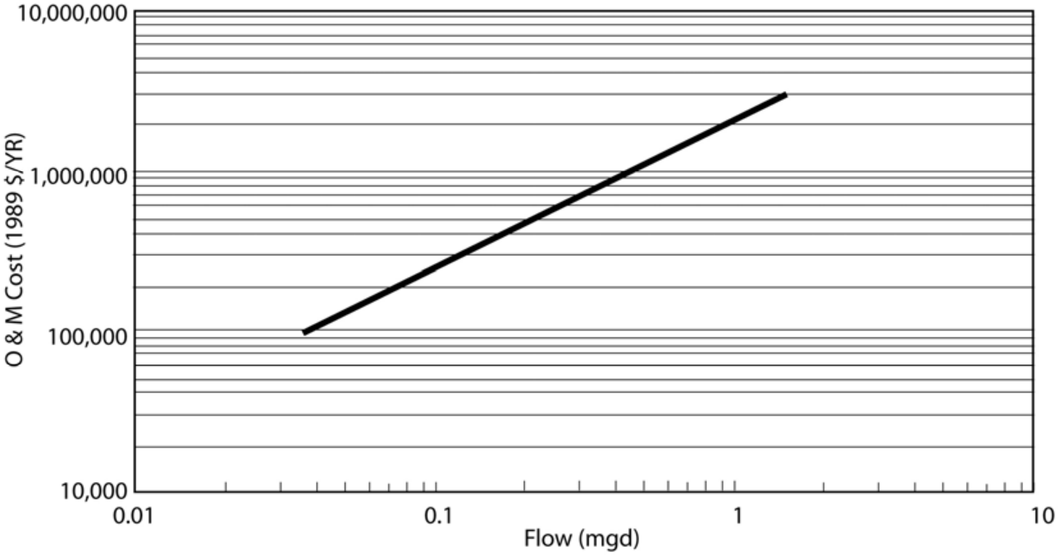


Figure 8-12. Dissolved air flotation capital costs, ENR CCI = 6076 (U.S. EPA, 2000a).

8.4.5 Sequencing Batch Reactor (SBR) Cost Estimation

The relationships shown in Figure 8-1 were taken from the U.S. EPA (2000a) concerning the CWT point source category. The data may not be totally accurate for pond systems, but are reasonable enough to provide guidance with regard to preliminary design.

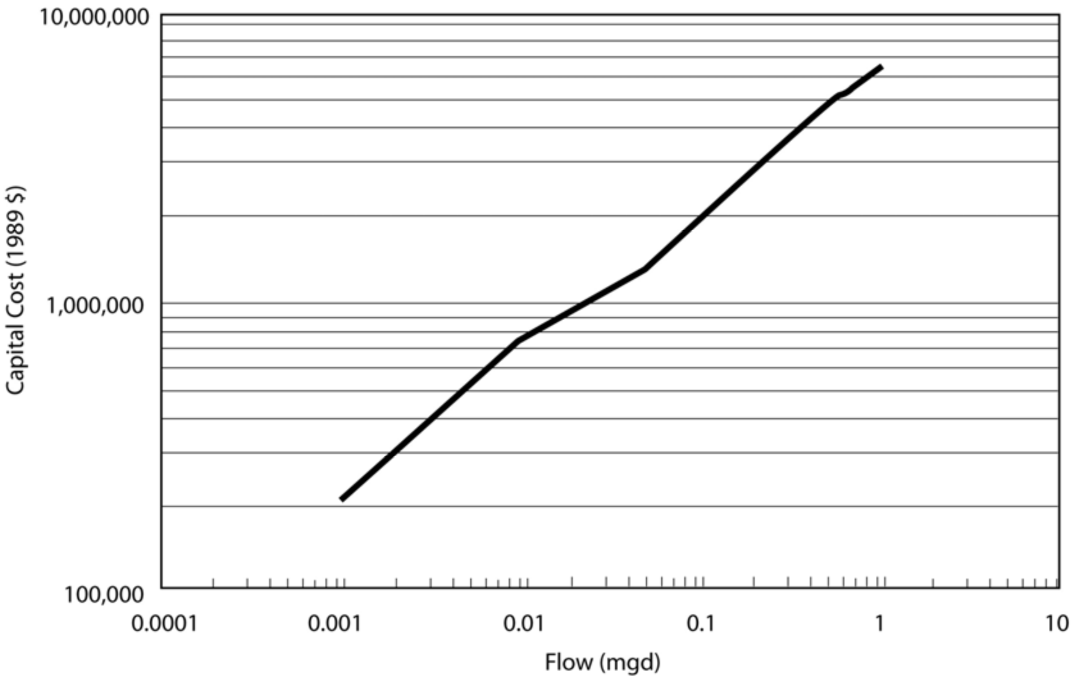


Figure 8-13. Sequencing batch reactor capital costs, ENR CCI = 6076 (U.S. EPA, 2000a).

8.4.6 Intermittent Sand Filter Cost Estimation

Given the limited cost data for intermittent sand filtration, a spreadsheet and tables were developed to assist design engineers in estimating costs associated with this polishing technique (Appendix C).

8.4.7 Intermittent Rock Filter Cost Estimation Procedure

See Section 8.4.6.

8.5 ENERGY REQUIREMENTS

Energy consumption is a major factor in the operation of wastewater treatment facilities. Many of the plans for water pollution management in the United States were developed before the cost of energy and the limitations of energy resources had to be taken into consideration. As wastewater treatment facilities are built to incorporate current treatment technology and to meet regulatory performance standards, the cost of the energy to run the processes must be considered more carefully in the designing and planning of the facilities. Planners and designers should seek out the most recent information on energy requirements so as to develop a system that incorporates the most efficient and affordable type and use of energy to treat wastewater to meet regulatory requirements consistently and reliably. Wherever possible, self-sustaining elements, such as alternative energy sources, capture and use of energy produced (i.e., CH_4), and uses of by-products (e.g., algae) should be considered.

8.5.1 Effluent Quality and Energy Requirements

Expected effluent quality and energy requirements for various wastewater treatment processes are shown in Table 8-3. Energy requirements and effluent quality are not directly related. Facultative ponds and land application processes can produce excellent quality effluent with smaller energy budgets. The same is true for several other combinations.

Table 8-1. Total Annual Energy for Typical 1 mgd System Including Electrical plus Fuel, expressed as 1000 kwh/yr (Middlebrooks et al., 1981).

TREATMENT SYSTEM	EFFLUENT QUALITY, mg/L				ENERGY (1000 KwH/YR)
	BOD_5	***TSS***	***P***	***N***	
Rapid infiltration (facultative pond)	5	1	2	10	150
Slow rate, ridge & furrow (facultative pond)	1	1	0.1	3	181
Overland flow (facultative pond)	5	5	5	3	226
Facultative pond + intermittent sand filter	15	15	-	10	241
Facultative pond + microscreens	30	30		15	281
Aerated pond + intermittent sand filter	15	15		20	506
Extended aeration + sludge drying	20	20	-	-	683
Extended aeration + intermittent sand filter	15	15	-		708
Trickling filter + anaerobic digestion	30	30	-	-	783
RBC + anaerobic digestion	30	30			794
Trickling filter + gravity filtration	20	10	-	-	805
Trickling filter + N removal + filter	20	10	-	5	838
Activated sludge + anaerobic digestion	20	20	-	-	889
Activated sludge + anaerobic digestion + filter	15	10	-	-	911
Activated sludge + nitrification + filter	15	10	-	-	1,051
Activated sludge + sludge incineration	20	20	-	-	1,440
Activated sludge + AWT	<10	5	< 1	< 1	3,809
Physical chemical advanced secondary	30	10	1	-	4,464