Capital Engineering Report

MULTI-AGENCY

Benchmarking Study

December 1999

MULTI-AGENCY BENCHMARKING STUDY

Capital Engineering Report

Participating Agencies

Central Contra Costa Sanitation District

City of Los Angeles Bureau of Sanitation

City of Portland Bureau of Environmental Services

East Bay Municipal Utility District

King County Department of Natural Resources

Orange County Sanitation District

Sacramento Regional County Sanitation District

In Consultation with

Damon S. Williams Associates, L.L.C.

December 1999

Data and information used to develop this report are from Fiscal Year 1997 (FY1997).

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Executive Summary

The purpose of this report is to describe a benchmarking study performed through the cooperative efforts of individuals involved in the implementation of capital improvement programs at seven public wastewater agencies. This report discusses how this group approached benchmarking, findings for performance and process benchmarking, identification of best practices in capital engineering, and lessons learned.

The public agencies involved in this study included Central Contra Costa County Sanitation District (CCCCSD), City of Los Angeles Bureau of Engineering (CLABE), City of Portland Bureau of Environmental Services (CPBES), East Bay Municipal Utility District(EBMUD), King County Department of Natural Resources (KCDNR), Orange County Sanitation District (OCSD), and Sacramento Regional County Sanitation District (SRCSD).

The first chapter describes each of these agencies in more detail, including their capital program organization, their capital program focus over the last seven years, and the accounting systems they used for collecting data used in this study.

The second chapter discusses how the capital project benchmarking effort was broken down into three steps including: performance benchmarking, process benchmarking, and linking performance and process benchmarking. Performance benchmarking involves development of comparative cost data on projects between each agency. Process benchmarking focuses on business processes—an approach to projects in the individual agencies. Linking the process and performance benchmarking efforts was performed to determine possible reasons why one agency is more cost effective than another.

The third chapter summarizes agency responses to process benchmarking questionnaires in each of 12 process topic areas. These areas include: capital improvement program development, partnering and dispute resolution, projects, identification of customer, document management, authority levels, change order processing, consultant procurement, staffing, construction contract approval, project management, alternative capital delivery methods, and inspection duties. These topics were identified by the group as highly critical in efficient performance of capital engineering at public agencies. No responses are included for the City of Los Angeles because it joined the group after process benchmarking was completed.

The fourth chapter presents the data gathered in graphical format. Because of regional differences in labor rates, data was benchmarked in hours, not dollars, to provide a standard basis for comparison. A template was developed to ensure consistency in the data. Each template represented one capital project. A total of 72 projects were sorted into one of two project types: collection system or treatment plant projects. Only completed projects, designed and constructed in the last ten years (1987 to 1996), were included in the study. The data was graphed for each agency and was plotted as a curve using the following axis:

1. Planning Hours vs. Construction Costs;
2. Design Hours vs. Construction Costs;
3. Construction Management Hours vs. Construction Costs;
4. Total Project Hours vs. Construction Costs;
5. Change Order Percent vs. Construction Costs
6. Ratio of Consultant to in-house engineers vs. Construction Costs;

7. Number of FTEs vs. Construction Costs; and
8. Design Costs vs. Construction Costs.

The fifth chapter provides a discussion on observations made from review of the performance benchmarking graphs, and possible causes for performance. The benchmarking team has recognized that the data used in this study has significant value in helping to focus improvement efforts for each contributing agency, but it does have significant limitations. The greatest value of the data is that it stimulates thought process among the individual agencies, allowing each agency to find ways to improve.

Following are selected findings from review of the performance benchmarking graphs.

- The data scatter on the change order percent versus contract amount graphs is substantial. Change order percentages vary widely for both collection system and plant projects and within individual agencies, indicating that they may be affected more by the specifics of the project rather than by a management approach. The graphs may also be indicating that change order rates by agency may vary based on each agency's view of how to handle extra work (i.e., by adding it as a change order or holding it over for a new project).
- The graphs tend to indicate that, as construction costs increase, agencies use more outside consultant hours (as compared to in-house staff hours). This may be done to avoid major staffing fluctuations.
- The graphs of design cost/construction cost versus. change order percent are relatively flat, indicating that spending more on design will not reduce the percentage of change orders. No effort was made to categorize the changes related only to design issues, so no correlation can be drawn between the design effort expended and the value of design-related changes.

The following selected trends were noted in the effort to link process and performance benchmarking.

Change Order Management: In the more-efficient agencies, change orders are regularly deferred to future contracts and only non-discretionary changes are completed. In the other agencies, non-discretionary and discretionary changes are executed with little or no concern. Additional study is required to determine whether deferral of changes is more efficient than incorporating changes with work in progress. The more-efficient agencies also have lower markups on change orders.

Consultant Procurement: The more-efficient agencies have streamlined processes for consultant procurement, particularly for smaller projects.

Scope Control: The more-efficient agencies tend to prepare tight scope on consultant agreements and aggressively manage the project to prevent changes in the scope of the work. This trend also applies to managing changes during construction.

Staffing: More-efficient agencies tend to keep staff "billable to projects," yet have overhead charge codes for work not attributed directly to projects.

Standardization: The more-efficient agencies tended to have more repetitive-type projects. They also had less formal procedures for project management, but used consistent filing systems.

Policy Issues: The more-efficient agencies had no M/WBE goals and requirements, had limited Board involvement in projects, and had corporate cultures which supported timely decisionmaking at relatively low levels in the organization.

The sixth chapter provides valuable lessons that were learned through the benchmarking effort and which should be applied for any future work by this group or any other group. Costs had to be collected at very summary levels due to differences in agency accounting systems. This made thorough evaluation of performance between agencies very difficult. A template was developed that this study recommends be used to collect costs in future capital engineering benchmarking efforts. The template includes detailed cost categories, and may be more conducive to performance comparisons. Change orders should be consistently categorized by the cause of the change, so the effects of increased design effort can be tracked on the percentage of changes caused by design oversights. Benchmarking activities take substantial time to gather, evaluate and present results. Actual durations for participants in this study are provided to help other agencies determine the level of effort required to participate in a benchmarking process.

Agencies were motivated to participate in benchmarking for a variety of factors, including cost competitiveness, ratepayer and taxpayer perceptions of government inefficiency, and as the first step in a continual improvement process. After completing this first step, several other process areas are recommended for investigation in the next phase, including personnel and technology issues, testing and startup issues, quality assurance/quality control approaches, the level of plant automation and other agency design-build contracting experiences. In addition, benchmarking efforts by private firms might be investigated to determine the extent and type of private-sector efficiencies, including other forms of contracting such as design/build and negotiated contracts.

Agency Descriptions

Central Contra Costa County Sanitation District

CCCCSD Agency Organization

Central Contra Costa Sanitary District (CCCSD) is a sanitary district with five elected directors who oversee and set the policy of the organization. CCCSD is responsible for the collection, treatment, and disposal of wastewater for a population of approximately 404,000 in central Contra Costa County. There are four departments: administration, engineering, collection system operations, and plant operations. The capital projects are principally done by the Engineering Department, with a relatively small amount done by the Plant Operations Department.

CCCCSD CIP Organization

During the period of the benchmarking study, the Engineering Department was organized into three divisions: the Plant Engineering Division, the Planning Division, and the Infrastructure Division.

The Plant Engineering Division handled the work associated with the design, inspection, and construction of treatment plant and pumping station facilities, source control and household hazardous waste collection activities, survey, mapping, and drafting.

The Planning Division was responsible for long-range planning, community planning, sewer system hydraulics analysis, capital budgeting, capital finance, and water reclamation services for other District departments and the general public.

The Infrastructure Division handled sewer and pumping station design and construction, permit, sewer service charge, and right-of-way issues.

CCCCSD CIP History

The principal purpose of the Capital Improvement Plan is to provide the District's Board of Directors with the information needed to formulate long-range policy regarding:

- Appropriate project priorities and schedules to assure continued effective accomplishment of program goals with the most efficient allocation of limited staff and financial resources.
- Human resources needed for completion of the projects proposed in the Capital Improvement Plan. The "capitalized" (District force account) labor, employee benefits, and administrative overhead budgets for each fiscal year's Operations and Maintenance Budget are derived from the Capital Improvement Budget. The Capital Improvement Plan forecasts appropriate long-term staff requirements.
- Sufficient financial resources for completion of the projects proposed in the Capital Improvement Plan.

In addition to providing the basis for policy decisions concerning the District's long-range Capital Improvement Program and management of the Sewer Construction Fund, the Capital Improvement Plan also serves as the framework for fee analysis and is the basis for the annual Capital Improvement Budget (the first year of the Capital Improvement Plan).

The discussion that follows gives an overview of the plan's goals and the programs proposed to meet these goals.

The District has identified three principal goals for its Capital Improvement Program:

- To protect public health and the environment by:
  - Meeting regulatory agency requirements;
  - Reducing sewage overflows/bypasses; and
  - Improving treatment/collection system reliability and safety.
- To accommodate future growth in the service area as approved by the city and county planning agencies responsible for land use policy decisions.
- To respond to issues of community concerns by:
  - Reducing the cost of operating and maintaining facilities;
  - Reducing objectionable odors;
  - Cooperating with other public agencies to avoid duplication of effort and improve service delivery;
  - Recycling water; and
  - Reducing power consumption through energy management.

Capital improvement projects are grouped into four programs: Treatment Plant, Collection System, General Improvements, and Recycled Water. A brief summary is provided below.

The Treatment Plant Program includes projects that will expand and/or update the wastewater treatment plant, including hydraulic/process capacity, solids handling, and air emission controls. This program also includes projects required to meet changing regulatory mandates.

The Collection System Program includes projects needed to reduce sewage overflows during wet weather and to serve new development in the District's service area. Specific near-term and long-term goals include upgrading the system to reduce overflows from manholes, improving the reliability of the District's pumping stations, and implementing projects to address structurally deficient and maintenance-intensive sewers.

The General Improvement Program is mainly concerned with the property and equipment needs of the District. Specific projects include property acquisition, automated drafting/mapping equipment, disaster command centers, and information system upgrades (computer hardware and software).

The District's Recycled Water Program had no completed projects available for inclusion in the database. The District has a program to provide recycled water for both irrigation of urban landscaping and industrial uses.

During the period of the benchmarking study, the majority of the expenditures concerned the improvement of facilities in the treatment plant. By the end of the benchmarking period, the balance had shifted to collection system projects, but only one large infrastructure project was complete and could be incorporated into the study. The preponderance of the design work was done with consultants, although there were exceptions with a few of the smaller projects. The construction phase was done with in-house staff (although, in some cases, District staff was supplemented with staff from consultants or independent, temporary inspectors).

The value of the annual capital budget for the period of this study averaged $24 million, with a low of $13.6 million and a high of $40 million. The 10-year capital plan had a value of approximately $200 million.

CCCCSD CIP Project Accounting

Each project is assigned a unique identifying number. Project phases are identified separately by planning, design, and construction phases. Within each phase, separate accounts are developed by the project manager to meet the needs of the particular project. Within the phases, there can be designations for many activities (e.g., project management, project engineering, survey, inspection, laboratory analysis/testing, archaeologists, claims, contractor payments, startup/acceptance testing, control systems implementation, in-house construction geotechnical, and legal). Consultants and contractors can be further identified by unique identification numbers as well as in-house salaries and benefits.

The cost for a particular phase was available in the financial report. The hours for both in-house and consultant labor were estimated based on an average value deemed appropriate for the particular project and time frame.

City of Los Angeles Bureau of Engineering Services

CLABE Agency Description

The Department of Public Works is responsible for management of wastewater collection and treatment for CLABE. The Department is managed by the five-member Board of Public Works, whose members are appointed by the Mayor. Under the responsibility of the Board of Public Works are four technical service bureaus (Engineering, Sanitation, Street Maintenance and Street Lighting) and three administrative bureaus (Accounting, Management Employee Services and Contract Administration). Wastewater capital improvement projects are designed and constructed by the Bureau of Engineering, while the Bureau of Sanitation operates and maintains the wastewater collection and treatment facilities.

CLABE CIP Organization

Since the period of time when most of the projects submitted for this study were designed and constructed, the structure of the Bureau of Engineering and its relationship to the Bureau of Sanitation has changed substantially. The previous structure was developed to handle the large capital programs required to accomplish full secondary treatment and the cessation of ocean disposal of sludge, the largest capital program ever delivered by the Department of Public Works. Under the previous structure, several divisions shared the planning, design and construction functions. Long-range planning and financial management was conducted by the Wastewater Program Management Division (WPMD), which was specifically responsible for the wastewater capital improvement program. Environmental documentation was also handled by WPMD. Several design divisions were created to handle treatment plant design, including the Hyperion Engineering Design Division (later called the Wastewater Treatment Engineering Division (WTED)), which handled facility design for the liquid treatment portion of the Hyperion plant as well as the City's three other treatment plants. The Solids Technology and Resource Recovery (STRR) Division was formed in 1990 and designed the expansion of the solids processing facilities at the Hyperion and Terminal Island plants. Construction management of the STRR projects was internally handled by the STRR Division, while all other construction was handled by the Hyperion Construction Division (later renamed the Wastewater Construction Management Division (WCMD) to reflect construction management responsibilities at other plants). Design and construction of the collection systems was the responsibility of the Collection Systems Engineering Division (CSED).

Under the current structure, financial management responsibilities have been transferred to the Bureau of Sanitation. CIP budgets are developed jointly between the Bureaus of Engineering and Sanitation; however, Sanitation retains final approval privileges for all capital projects. All treatment plant design and construction management responsibilities are being consolidated into the Environmental Engineering Division (a consolidation of the former STRR and WTED). Collection system design and CM will be managed by CSED. WCMD is currently being downsized, but will remain in force until all construction issues are finished with the full secondary contractors.

CLABE CIP History

CLABE's wastewater system includes four treatment plants and over 6,500 miles of sewers. Capital expenditures on the system have averaged $131M over the last 10 years. The majority of treatment plant projects submitted for this benchmarking study were a part of the full secondary expansion of the Hyperion Treatment Plant. CLABE entered into a consent decree with the EPA in 1980 to cease ocean disposal of sludge and later to construct full secondary treatment for 450 MGD of flow. CLABE had initiated a major master planning effort, called the Wastewater Master Plan, with a planning horizon of 2050. This plan encompassed the following elements:

- Expansion of the Hyperion Treatment Plant to full secondary treatment, including the installation of 450 mgd of high-purity oxygen secondary;
- Expansion of digestion capacity at Hyperion by the installation of 18 new egg-shaped digesters;
- Expansion of the biosolids processing capacity, including the installation of high-capacity, high-solids centrifuges;
- Installation of tertiary filters at the Terminal Island Treatment Plant;
- Installation of a second 40-mgd liquid process train, doubling the treatment capacity of the Tillman Treatment Plant;
- Process and operational enhancements at the CLABE's outlying plants;
- Major environmental documentation and permitting efforts; and
- Public relations for these expansions.

Earlier, CLABE was involved with a regional residuals management plan for the Los Angeles/Orange County Metropolitan Area (LA/OMA) that resulted in the recommendation that the City implement drying, combustion and energy recovery at the Hyperion Plant for its generated biosolids. Some of the projects submitted for the study are improvements, replacements and optimizations of the solids combustion processes initiated under LA/OMA.

Collections systems projects during this time were mainly concentrated on the systematic upgrade and replacement of existing sewer lines and the rehabilitation of existing pumping plants.

CLABE CIP Project Accounting

CIP expenditures are planned annually for a five-year planning horizon. CIP budgets are approved on an annual basis for the following year by the Board of Public Works and are included in the Mayor's annual budget, which is approved each year by the City Council.

Project costs are accrued against project work orders. For project management purposes, projects are subdivided into seven phases: planning, pre-design, design, bid and award, construction management, commissioning, and optimization. However, costs in CLABE's Financial Management Information System (FMIS) are only segregated into planning and construction management. Further, hours are recorded for CLABE personnel only; consultant charges are recorded as invoice costs only.

In developing costs for this study, hours and costs for CLABE forces were taken directly from FMIS. Consultant costs for the full secondary projects (which constitute the major portion of the overall costs) were also taken from FMIS, but hours were estimated based on average hourly costs. The Environmental Engineering Division (EED) maintains a separate in-house database to record all hours and costs, both for CLABE and consultant forces. FMIS costs for EED projects submitted for this study were verified and adjusted against this independent database.

Collection system hours and costs are also tracked in a separate database by the Collections Systems Engineering Division. In this case, however, FMIS data, which includes charges by all

Division and Bureaus against a collection system project, is directly incorporated into the Division's database. The costs submitted for this study were taken directly from the CSED database.

City of Portland Bureau of Environmental Services

CPBES CIP Organization

CPBES involves four of the five main groups of the organization in planning and implementing its CIP). Table 1 identifies how primary responsibility, support and review roles shift as a project moves from planning through design and construction. The CIP Management Group provides on-going oversight for each project.

Two planning sections within the Systems Development Group have the primary responsibility for system-wide planning. This group works in collaboration with the Engineering and Technical Services division of the Wastewater Group on treatment plant and pump station planning. It also works in collaboration with the various sections of the Engineering Services Group on storm water management, CSO abatement and sanitary sewer planning. The planning sections also review all CIP project requests that are submitted during the annual development of the approved list of CIP projects.

Subsequent to planning, divisions within the Engineering Services Group and the Wastewater Group are responsible for preparing CIP project requests and assigning project managers to guide the projects through design and construction. At the conclusion of each major phase (i.e., predesign, design, bidding and award, construction, testing and startup), the project manager must obtain the concurrence of the CIP Management Group to move on the next phase. Each design phase project manager is responsible for preparing a project work plan and assembling a design team and a project review team, as well as securing permits and right-of-way when required.

After bidding and award, a construction phase project manager is assigned to the project. The construction manager is responsible for guiding the project through construction, testing, startup and project documentation.

Table 1 Activity and Responsibility Matrix P = Primary Responsibility, S = Support, R = Review, O = Oversight		
Major Activity	**Responsibility**	
Planning		
Environmental	**P**	• Systems Development/Regulatory Planning
	S/R	• Wastewater Group/Treatment O&M • Wastewater Group/Engineering & Technical Services • Industrial/Solid Waste Group/Environmental Compliance • Industrial/Solid Waste Group/Industrial Source Control
	O	• CIP Management Group
Planning Studies (Facilities Plans)	**P**	• Systems Development/Facilities Planning
	S/R	• Wastewater Group/ Engineering & Technical Services • Wastewater Group/Treatment O&M
	O	• CIP Management Group
Permitting and Right-of-Way Acquisition	**P**	Design Project Manager from one of the following: • Engineering Services Group/Storm-Surface Water Design • Engineering Services Group/Maint. -Sanitary Design • Engineering Services Group/Development Services • Wastewater Group/ Engineering & Technical Services
	O	CIP Management Group
Design	**P**	Design Project Manager from one of the following: • Engineering Services Group/Storm-Surface Water Design • Engineering Services Group/Maint. -Sanitary Design • Engineering Services Group/Development Services • Wastewater Group/ Engineering & Technical Services
	P/S	Design team from one, or more, of the following: • Engineering Services Group/Storm-Surface Water Design • Engineering Services Group/Maint. -Sanitary Design • Engineering Services Group/Development Services • Wastewater Group/ Engineering & Technical Services • Consultants
	R	Project Review teams from the divisions with primary responsibility plus: • Engineering Services Group/Construction Services • Engineering Services Group/Material Testing-Geotech • Wastewater Group/Appropriate O&M sections
	O	• CIP Management Group

Table 1 (continued) Activity and Responsibility Matrix P = Primary Responsibility, S = Support, R = Review, O = Oversight		
Major Activity		**Responsibility**
Construction		
Management	**P**	• Construction Project Manager from Engineering Services Group/Construction Services, or Contract Employees
Inspection	**P**	• Inspectors from Engineering Services Group/Construction Services, or Contract Employees
	R/O	• Construction Project Manager
Technical Support/	**P**	• Construction Project Manager
Engr. Services (submittals, RFIs)	**S**	• Design Project Manager & Design Team (see Design responsibilities) • Wastewater Group/I&C Engineering & Tech. Support
Testing/Startup	**P**	• Construction Project Manager
	S	• Design Project Manager & Design Team (see Design responsibilities) • Wastewater Group/Appropriate O&M sections (for pump station and treatment plant projects) • Wastewater Group/I&C Engineering & Tech. Support
	R	• Wastewater Group/Appropriate O&M sections (for pump station and treatment plant projects)
Documentation	**P**	• Construction Project Manager
	S	• Design Project Manager & Design Team (see Design responsibilities) • Wastewater Group/Engineering & Technical Services (for pump station and treatment plant projects)
	R	• Wastewater Group/Treatment Plant O&M (for pump station and treatment plant projects) • Wastewater Group/Collection System O&M (for collection system projects)
	O	• CIP Management Group

CPBES CIP History

The CIP for CPBES has averaged just over $101 million per year in projected expenditures for the last five years. The approved capital budget for the next fiscal year is about $92 million.

Major capital improvement activities over the last five to seven years include the Mid County sewer project, which brought sanitary sewer service to approximately 53,400 previously unsewered properties. The Mid County project was implemented in response to a state order and agreement with CPBES which required that residential on-site sewage disposal systems be phased out in mid Multnomah County. The project began about 1988 and will be completed in 1998 at a total cost of approximately $330 million.

In the last five to seven years, a series of treatment plant modification projects has also been undertaken to upgrade the Columbia Boulevard Wastewater Treatment Plant (CBWTP). The projects are primarily directed at improving operational efficiencies and making safety/workplace environmental improvements. The most significant projects include:

- Aeration basin modifications that added fine-bubble air diffusers and increased flexibility to the secondary process;
- Additional sludge cake and handling facilities for the biosolids land application program;

- Renovation of a 36-acre biosolids storage lagoon; and
- Inception of a plant-wide odor control program.

In addition, a new 300-mgd Headworks facility (with sewage pumping, bar screens, grit removal, grit and screenings storage, and odor control) was designed and constructed between 1993 and 1998 at a total project cost of approximately $30 million.

Another part of the CIP is directed at abating water pollution during wet weather from combined sewer overflows (CSOs). The CSO Abatement Program is driven by a compliance order from the state of Oregon to control discharges from all CSO outfalls by the year 2011. Approximately $300 million has been committed through mid-2002 for this program. The total CSO abatement program cost is approximately $750 million.

Another part of the CIP is directed at systematically replacing, reconstructing or rehabilitating the sewer collection system. The average estimated need for this program has been about $14 million per year over the last five years. The surface water management element of CIP has included expenditures of approximately $6 million per year over the last five years. The other element of the CIP is focused on expanding the City's sewage collection system and on supporting new development. Expenditures for collection system development have averaged about $7.5 million per year over the last five years.

CPBES CIP Project Accounting

The primary source of recent project cost data used as input to the capital project performance benchmarking was CPBES's Project Tracking System (PTS). PTS cost data were available for fiscal years 1996-97 and 1997-98. The PTS "accounts payable" report is a record of all payments on the project except agency labor. The PTS "payroll" report is a record of all agency labor costs and hours on the project. The breakdown of labor between planning, design, and construction phases is provided by the type of work code used on time sheets and presented as a report parameter on PTS reports. The more recent project cost data also includes general fund overhead that has been assigned to each project.

The project manager's files, project close-out reports and consultants' invoices were used to capture capital project cost data for projects prior to FY1996-97. The consultants' labor hours were either available on the invoices, or were back-calculated using average rates. Project cost data for these older projects is less reliable than the cost data captured in PTS.

East Bay Municipal Utility District

EBMUD Agency Organization

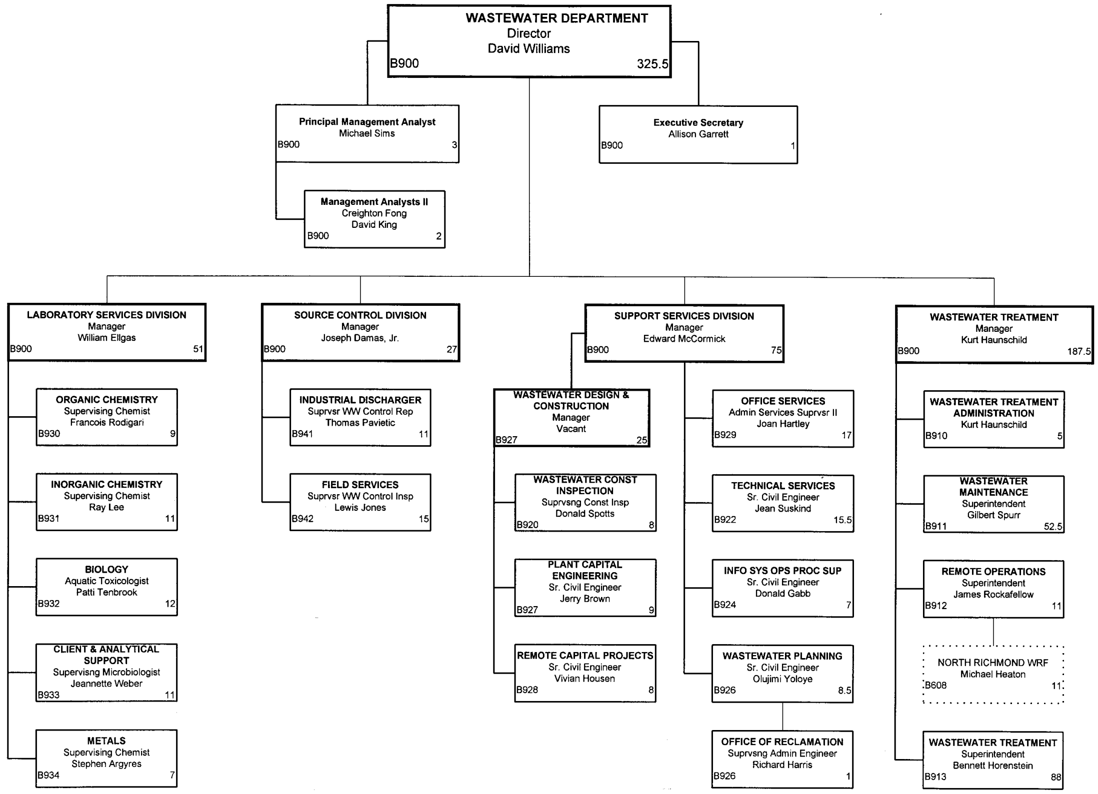
The seven elected Board of Directors oversee all activity of EBMUD's Water System and Wastewater System. The Wastewater Department includes four divisions: Wastewater Treatment, Support Services, Laboratory, and Source Control. The Wastewater Department relies on the Support Services Division (SSD) to plan and implement the capital budget. Other groups outside of SSD, but still within the Wastewater Department, provide assistance in the implementation of capital projects. The Wastewater Treatment Division operates and maintains the District's wastewater facilities. The WTD supports the implementation of capital projects by identifying new capital improvements, coordinating construction within operating facilities, performing design review for operations and maintenance issues, final testing, and commissioning of completed capital facilities. The Laboratory Services Division and Source Control Division are only involved with capital improvements associated with the buildings where they perform their work. Services such as legal counsel, accounting (payables and receivables), public affairs, M/WBE and AA compliance, purchasing, regulatory compliance, properties and human resources, are provided by other groups outside SSD, outside the Wastewater Department but still within the EBMUD organization.

EBMUD CIP Organization

The Support Services Division (SSD) provides engineering and technical support to the Wastewater Department; manages the implementation, design and construction of capital programs; and maintains the Wastewater Department's computer system. During the period when projects included in this study were performed, the SSD was reorganized to accommodate changing capital program needs. The annual average CIP budget has been gradually decreasing over the last five years from $60M to about $30M.

During 1991-1995, the SSD consisted of seven groups. The Project Management, Major Capital Projects, Remote Wet Weather Facilities, and Plant Engineering sections were largely responsible for the capital improvements put into service during this period. Tin general, the Project Management Section handled the planning and design aspects of large projects, managed consultants, and acted as the interface between consultants and the Wastewater Treatment Division. More than 90% of the engineering planning and design work was contracted out to consultants. The Plant Engineering Section was responsible for planning, design and construction of smaller projects (generally less than $1M construction cost). Its function was to assist the Wastewater Treatment Division with small capital improvements mainly required to maintain the existing infrastructure and that needed to be done quickly. The Major Capital Projects Section and the Remote Wet Weather Facilities Section managed construction contracts for the larger capital projects. Construction of facilities remote to the Main Wastewater Treatment Plant were managed by the Remote Wet Weather Facilities Section and larger projects at the Plant were managed by Major Capital Projects. The Major Capital Projects Section also included a construction inspection staff. The general practice has been to have an EBMUD inspector as lead inspector for all capital projects.

Wastewater Department Organization



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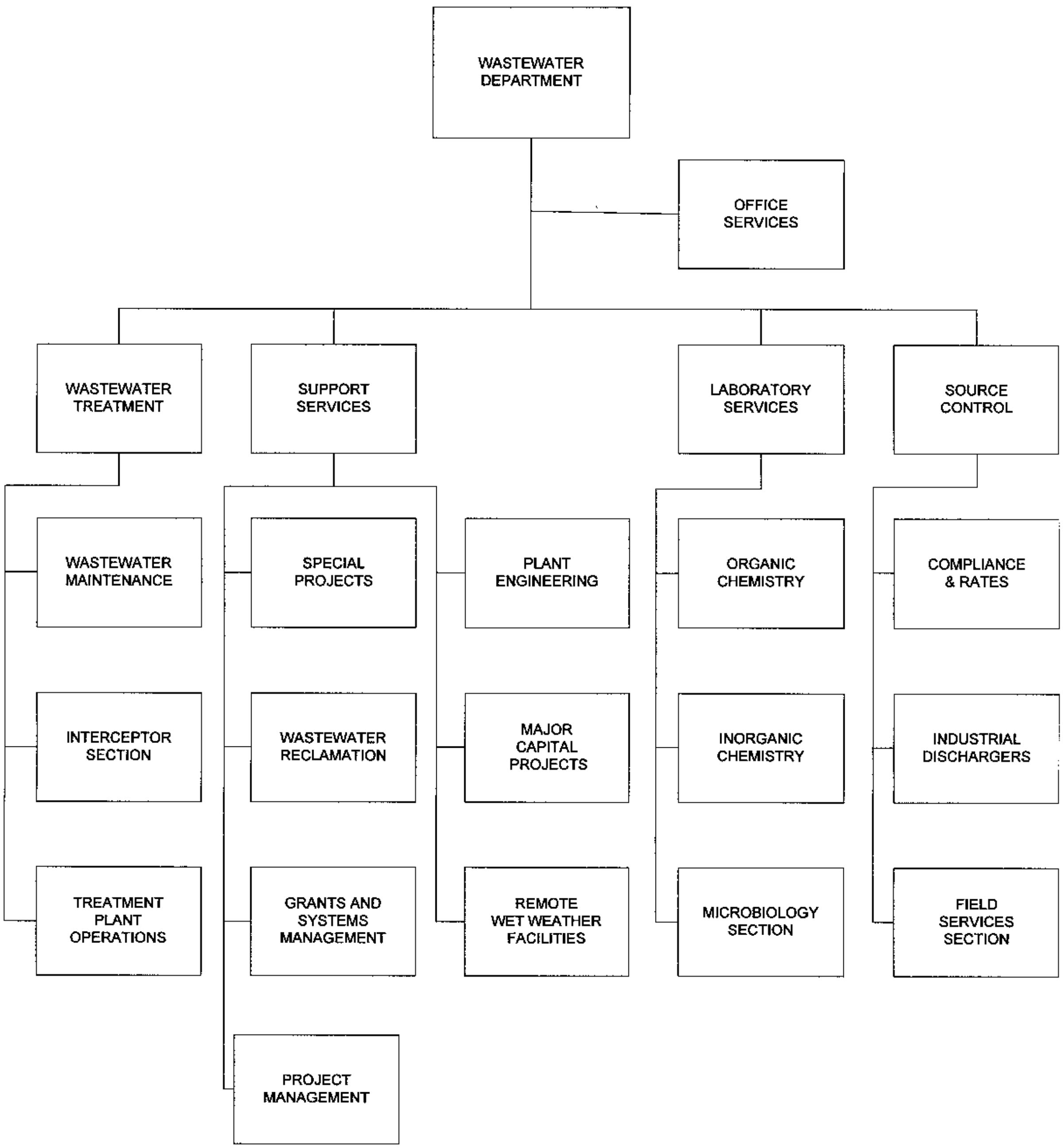
WASTEWATER DEPARTMENT



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Other groups in SSD were involved in the capital program but handled other tasks as well. The Special Projects Section provided technical support, special studies, and research and development into new technologies. The Wastewater Reclamation Section managed the capital program associated with developing the reuse of wastewater in place of potable water, working closely with the EBMUD Water System. The Grants and System Management Section was responsible for providing drafting and graphics support, public affairs assistance, maintaining the Wastewater Department's computer system and assisting in the preparation of the capital and operating budgets.

An SSD reorganization in 1995 consolidated functions and reduced the number of groups from seven to six. The reorganization also brought additional responsibility to the SSD for clerical support to all Divisions within the Wastewater Department. A new Planning Section was created to provide more of a focus on coordination of capital projects and develop long-term strategies for maintaining the infrastructure and regulatory compliance. The Planning group also performs all reclamation planning work. Design and construction of capital projects was consolidated into two sections instead of three: Plant Capital Engineering and Remote Capital Engineering. The plant groups do all design and construction of capital projects at the main wastewater treatment plant and the remote group does all design and construction at the remote facilities. The Project Management Section was eliminated. The Wastewater Inspection Section provides inspection services to all capital projects. The Process Engineering Section performs pilot studies, provides operational technical support, and maintains the Wastewater Department computer systems.

EBMUD CIP History

Capital improvements for the period 1991 through 1995 focused largely on the implementation of the $240M Wet Weather Program. This regulatory-mandated program involved construction of four new wet weather treatment facilities, a major expansion and upgrade of the MWWTP, extension of interceptor pipelines to carry wet weather flows, and upgrades to existing wastewater pump stations. Other CIP programs during this period included projects associated with biosolids management, air quality, operational efficiencies, wastewater reclamation and reimbursable projects for other agencies.

The schedule requirements for completing the Wet Weather Program allowed few engineering resources to be used for maintaining and upgrading the older facilities already in place. So as the Wet Weather Program wound down in 1995, the capital improvement plan shifted focus to maintaining the infrastructure, finding ways to improve operational efficiency, and reclamation.

EBMUD CIP Project Accounting

Capital project budgets establish limits for project spending and are approved by the Board of Directors as project appropriations each year with the Wastewater five-year Capital Improvement Plan. These limits are for the total project and do not limit spending on particular items within the budget, although policies exist that have this effect. Actual project costs are accumulated against job numbers, which are created specifically for the project. In most cases, job numbers are issued for each project phase; however, there are occasions where only one job number exists for the entire project. Project Managers have the capability to retrieve actual project costs for each month of each project phase that the project is in progress, including number of hours and dollars spent by a budget unit for various types of expenditures (i.e., labor, consultant, materials, construction, etc.).

Costs for capital projects included in this study were determined from records contained in the EBMUD financial information system (FIS). The projects for this study were selected based on the following criteria:

- Project completion must be within the last seven years;
- Project size varies from $500k to $100M;
- Both in-house design and consultant design included; and
- Persons who worked on the project day-to-day must still be working in the Wastewater Department and will provide the required project data.

These criteria were established primarily to ensure a broad variety of projects for the study and to ensure that the most accurate information possible was provided.

District labor hours and dollars for each project phase were determined from the FIS cost reports (FIS031). An instruction sheet was developed so that all costs were allocated in a consistent manner from one project to another, even though different people were gathering the information. The consultant labor hours and dollars were taken from actual invoices or original agreement estimates, where available. In cases where these documents were not available, estimates of consultant labor hours were created based on a standard $100/hr rate applied to consultant dollars included in the FIS reports. Any project costs not allocated to either District or consultant labor were allocated to administrative and general expenses.

King County Department of Natural Resources

Agency Organization

King County is a general-purpose government that provides regional services (roads, transit, law enforcement, parks, etc.) on a countywide basis, and contracted services to cities within the County. King County is governed by a County Executive and a 13-member Council elected by district.

The King County Department of Natural Resources (KCDNR) includes divisions for Wastewater Treatment, Water and Land Resources, and Solid Waste, plus a commission for Marketing Recyclable Materials. The Wastewater Treatment Division (WTD) provides wholesale wastewater transport, treatment, and disposal service to 17 cities and 18 local sewer and water districts, collectively known as component agencies.

Wastewater treatment operations, maintenance, administration, and capital improvement functions are located within the Wastewater Treatment Division. Source control, public outreach, water quality monitoring, and environmental functions are located within the Water and Land Resources Division.

Implementation of capital projects occurs in several different sections within the WTD. The Capital Improvement Section (CIP) is responsible for the majority of the capital program for the division, but Facilities Planning and Biosolids perform capital projects as well. The long-range facilities planning efforts are managed by the Facilities Planning section as capital projects, and the Biosolids group has managed capital projects to support the biosolids program.

KCDNR CIP Organization

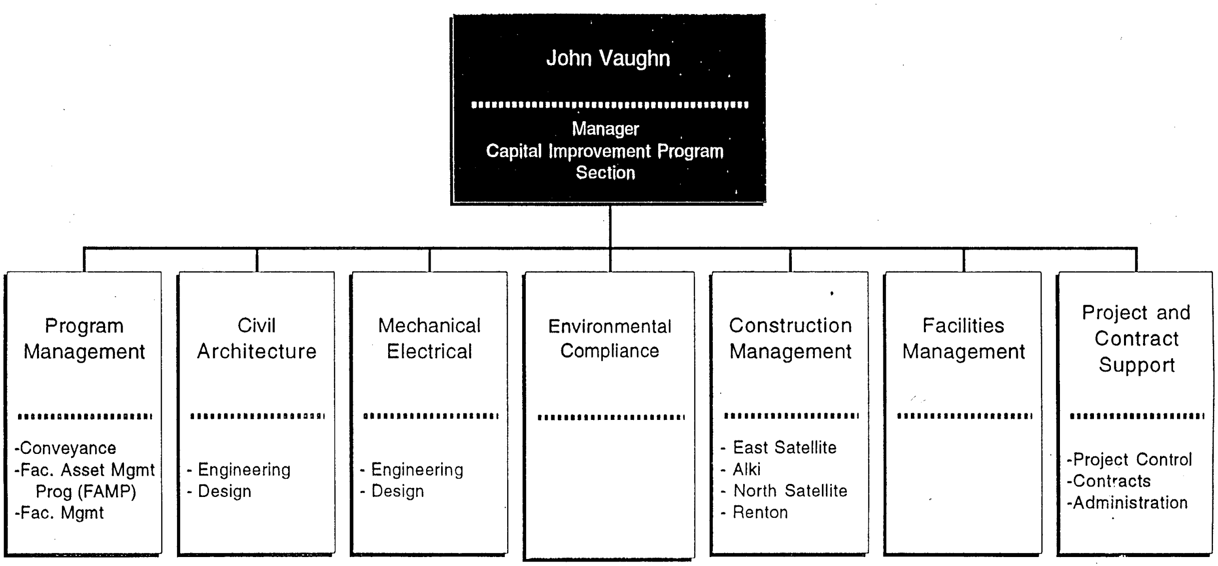
Capital projects in KCDNR Wastewater Treatment Division (WTD) arise from two sources: major facilities long-range planning efforts, and Operations and Maintenance requests.

The WTD Facilities Planning Section has the primary responsibility for completing all planning studies and efforts. They may be assisted by various groups in the WTD CIP Section (e.g., Environmental Compliance). Once the project is ready for predesign, Facilities Planning transfers the project to the CIP Section for implementation.

Projects arising from Operations and Maintenance requests generally require no facility planning efforts and come directly to the CIP Section for execution.

The CIP Section has primary responsibility for capital project management from predesign through project close out. However, other groups within the section or other departments may have major supporting roles for various phases or activities as shown in Table 2.

Table 2 **KCDNR CIP Capital Project Management Supporting Roles**	
Activity	**Major Supporting Role**
Permitting/Right of Way	DNR Water & Land Resources Division Open Space Section
Design	WTD CIP Engineering Group or Outside Consultant
Construction Contract Management	WTD CIP Construction Group
Construction Inspection	WTD CIP Construction Group
Construction Engineering Support	WTD CIP Engineering or Outside Consultant
Testing/Startup	WTD CIP Construction Group with WTD Operations support
Documentation—As-Builts	WTD CIP Engineering Group
Documentation—O&M Manuals	WTD Technical Publications
Special Considerations—Procurement of Consultants and Construction Contracts	Department of Finance Professional & Construction Services Procurement Division and M/WBE Division, Department of Information & Administrative Services Risk Management
Special Considerations—Change Order Review	For projects >$10 million, Department of Finance Construction Administration Support For project <$10 million, WTD Finance Section



KCDNR CIP History

The primary focus of the KCDNR capital improvements program for the last five to seven years has been the completion of the Secondary/CSO Program. The goal of this major program of over one billion dollars was to comply with mandated regulatory requirements to upgrade all treatment facilities to secondary treatment discharge limitations, as well as reduce combined sewer overflow events.

The Secondary/CSO Program began in the late 1980s and construction of most projects was underway by the early 1990s. The program included the over $500-million upgrade of the West Point Treatment Plant to secondary treatment, the second phase expansion of the East Division Reclamation Plant, and the conversion of the Carkeek and Alki primary treatment plants to stormwater treatment facilities.

Since 1995, there has been an increase each year in smaller capital projects that address maintaining the infrastructure, seismic upgrades, exploring wastewater reclamation and complying with underground storage tank (UST) regulations. Most seismic upgrades and UST compliance projects are complete. Many current projects address replacement of equipment reaching the end of its service life, modification of facilities to address safety concerns, or enhancement of facility operations and maintenance.

A new Regional Wastewater Services Plan has been developed that outlines needed improvements to the existing wastewater system, including a new treatment plant. Implementation of this new plan, once formally adopted, will increase the annual CIP significantly.

From 1992 to 1996, the annual expenditure rate for the CIP was over $160 million. From 1996 through 1999, the CIP annual budgets are projected between $100 and $116 million as most Secondary/CSO Program projects are completed. Projected annual budgets in 2000 and beyond will be between $130 and $180 million as work on the Regional Wastewater Services Plan starts.

KCDNR CIP Accounting

Two different accounting systems were in use for tracking costs for the projects included in the database. Prior to September 1995, the King County accounting system (ARMS) was used. After September 1995, the new Integrated Business Information System (IBIS) was used for accounting.

The ARMS accounting system collected staff labor hours and project costs for projects based on a series of project numbers established by the project manager. In general, ARMS costs and staff hours were not categorized by phase (planning, predesign, final design, etc.), unless the project manager set up project numbers to collect costs by phase.

The IBIS accounting system uses only one project number for each project. The IBIS system uses a “phase” field to segregate costs into planning, predesign, final design, construction, closeout, land acquisition and contingency phases. When the accounting system converted from ARMS to IBIS, all costs in ARMS were arbitrarily moved to the construction phase in IBIS. Neither system allowed for separating costs by phase, so costs were allocated to phases based on estimated phase duration.

Both ARMS and IBIS use account numbers to designate the type of cost. Account numbers were used to separate costs into the template categories. The Contract Payment System 2 (CPS2) system was used to collect individual consultant and construction contract costs. The CPS2 system is used to process consultant and construction payments. It tracks proposed work changes, change orders, payment history and contract history for individual contracts. Consultant hours were estimated using an average rate and the total amount paid as shown in CPS2.

Orange County Sanitation District

OCSD CIP Organization

OCSD's CIP is administered through the Engineering Department.

The Table 3 shows the OCSD's CIP outlay for the period from which the benchmarked projects were taken.

Table 3 Joint Works Capital Outlay Schedule ($ in thousands)							
1990-91	**1991-92**	**1992-93**	**1993-94**	**1994-95**	**1995-96**	**1996-97**	**1997-98**
83,296	78,331	43,341	33,420	21,682	23,479	51,639	49,332

The Engineering Department is divided into two divisions: Planning and Design (P&DD), and Construction.

P&DD is responsible for all aspects of the CIP program from inception through Notice to Proceed on all construction projects. P&DD is divided into the following sections:

- Planning;
- Plant Design;
- Collections System Design;
- Small Projects;
- Automation.

The Planning Section is responsible for all short-range and long-range planning of facilities, including Master Plan preparation. The Planning Section is also responsible for administering the California Environmental Quality Act (CEQA). The Plant Design Section and the Collections Design Section each are responsible for overseeing the CIP for their respective areas. Each section prepares design studies through construction plans and specifications through the use of outside consultant contracts. Each section is responsible for all aspects of the projects, including permitting and right-of-way acquisition. The Small Projects Section prepares construction plans and specifications as well as small design studies for projects that are generally less than $100,000 each. Approximately 50 such projects are completed on an annual basis. The automation section is charged with all aspects of automating the Districts' facilities.

The Construction Division is responsible for all CIP Projects from the Notice to Proceed through all aspects of construction to the final close-out of the project. Typical duties in the Construction Division include inspection, project management, shop drawing coordination and review, change orders, testing and start-up oversight, and construction documentation (field as-builts). Final as-built documentation, and Operations and Maintenance (O&M) manuals are the responsibility of the Planning and Design Division.

The O&M Department plays a major role in all CIP Projects. O&M is involved, as a participant and a customer, in review of all aspects of the master planning work by CSDOC, as well as in the design review process of each capital project. O&M has personnel assigned to each capital project during the pre-design and design phases of every project. The Districts make every attempt to implement customer input in the design phase of each project in order to avoid more costly change orders later.

OCSD CIP History

1989 Master Plan Components

OCSD completed the development of a master plan for all of its facilities in 1989. The 1989 Masterplan set the CIP program for the benchmarked period in this report.

The focus of the 1989 Master Plan was to plan ahead for the NPDES permit renewal process and to provide a long-range plan for development of wastewater facilities. The planning process included:

- A scientific review of coastal ocean water quality to summarize effects of current discharge on ocean water quality;
- A 30-year facilities Master Plan for wastewater collection, treatment and disposal facilities necessary to accommodate future growth under several different discharge requirement scenarios;
- A financial plan to evaluate the financial impact of facility needs on each individual district and to determine user fees and connection fees necessary to pay for new facilities;
- An EIR to address the impacts of facility construction and operation and to weigh the environmental effects of the different discharge requirement scenarios;
- A public participation program to inform the public of the planning program and to receive public input in the permit renewal and decision-making process; and
- Application to the Environmental Protection Agency (EPA) for a new NPDES permit.

The evaluation of scenarios considered operational efficiencies and cross-media environmental tradeoffs.

Maintaining Infrastructure

Infrastructure maintenance was studied in terms of reliability analysis. Reliability criteria were established for influent sewers, pump stations and treatment works. The reliability analysis identified features such as redundant or standby components, emergency power supplies and replacement parts necessary to provide uninterrupted service.

Regulatory Compliance

The Master Plan focused on satisfying anticipated regulatory requirements governing the discharge of liquid and gas streams from the Districts' two treatment plants. For planning purposes, three scenarios for regulatory requirements were investigated and compared:

- California Ocean Plan—75% solids removal;
- Maintain existing NPDES permit concentration limits; and
- Full Secondary Treatment.

The Master Plan considered that a change in regulations in one medium, such as the ocean discharge, might very well impact other media. The increased solids produced by increasing secondary treatment, for example, produces more solids, which impacts landfills and increases overall air emissions.

Seismic Upgrades

In recognition of the potential damage that could occur in the wake of a major earthquake, flood, or other disaster, OCSD incorporated a disaster preparedness plan as an element of the Master Plan. The disaster preparedness plan identified areas of potential vulnerability to damage, recommended measures to reduce OCSD's vulnerability, and developed emergency response procedures in the aftermath of a disaster situation. Following structural analysis of major collections and plant facilities, specific seismic retrofit projects were identified.

Reclaimed Water

Considering the need for additional reclaimed water supplies in Orange County and state of California,, the potential institutional constraints to future expansion of the two existing treatment plants, as well as the benefits of developing additional reclamation facilities, the OCSD pursued a program of upstream water reclamation as a key element of the Master Plan. Eighteen potential sites within the OCSD service area were identified and evaluated using ranking criteria. Three priority sites were identified and studied in further detail. The priority sites varied in flow capacity from 5–25 mgd.

Biosolids

The purpose of the biosolids management analysis was to identify viable reuse/disposal options for the OCSD biosolids management program. Twelve basic alternatives, along with several options within each, were developed. These alternatives were further analyzed and screened, the results of which indicated several potential directions for the Districts' future program. The implementation program was categorized into ongoing/immediate and long-term programs. The overarching principles for biosolids management from the Master Plan were:

- 100% beneficial reuse of biosolids;
- Maintain an in-county disposal plan; and
- Maintain contracts with multiple reuse/disposal sites.

OCSD CIP Project Accounting

The accounting system in place for the duration of the benchmarked projects tracked both staff hours and costs. Cost accounts were maintained for labor, overhead, materials, outside services, and travel. Records were maintained of monthly charges to each work order number. Capital improvement projects sometimes shared a work order number for their design phases. The recorded hours were sometimes obviously in error and allocation of charges to outside services was unreliable.

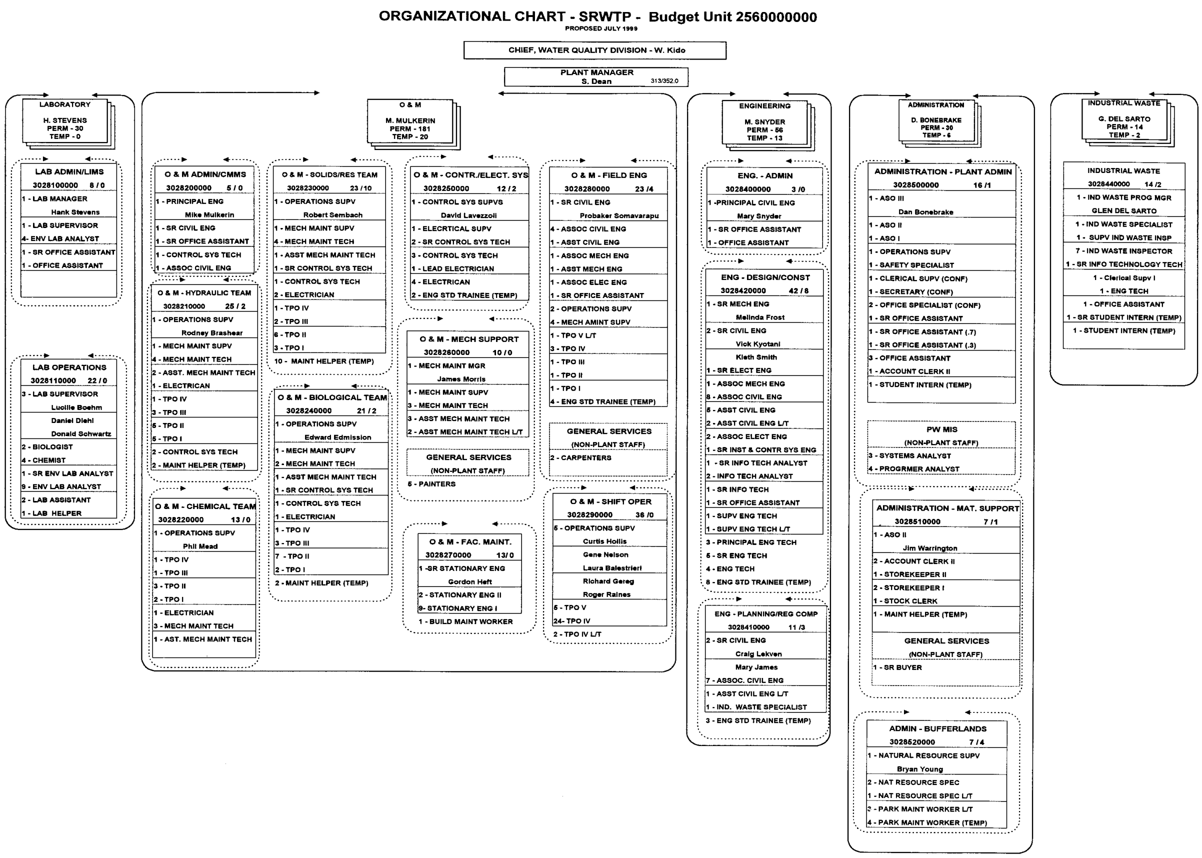
Actual costs for consultants and construction contractors reported in the study were as stated in their contracts and contract changes. Recorded staff costs and hours were typically in agreement and were reported in the study. Otherwise, staff hours were derived from the records for costs. Hours were converted into dollars using an average hourly rate of $38.60 for wages and benefits. Staff costs were allocated to project phases based on charges during the estimated period of the phase. The planning phase is poorly documented and under-reported because work order numbers were not established at the beginning of the phase. For projects split during the design phase, the consultant costs were divided in proportion to the resulting construction contracts.

Sacramento Regional County Sanitation District

SRCSD Agency Organization

SRCSD provides wastewater service to the urbanized areas of Sacramento County, California, including the cities of Sacramento, Folsom, and Citrus Heights. The SRCSD Board is comprised of the five County Supervisors plus a representative from each of the city councils.

SRCSD staff is provided by Sacramento County. The organization chart shows the most relevant portions of the organizational structure. The County structure includes five agencies, including the Public Works Agency (PWA). The PWA includes four Departments: County Engineering, District Engineering, Administration, and General Services. Overall responsibility for wastewater services resides in the Department of District Engineering, Water Quality Division.



The Water Quality Division has two separate business units. One unit is the Sacramento Regional Wastewater Treatment Plant (SRWTP) and the Collection System Unit. Each of these business units has its own operations and maintenance, administration, and engineering staff. The SRWTP business unit also has a laboratory section.

The Sacramento Regional Wastewater Treatment Plant is a major plant that serves almost the entire service area. The service area population exceeds one million. The plant provides secondary treatment with a pure oxygen-activated sludge process. The effluent is chlorinated and dechlorinated prior to discharge to the Sacramento River.

SRCSD CIP Organization

The Department of County Engineering and the Department of District Engineering have major responsibilities in construction of SRWTP facilities, while other departments within the Public Works Agency and other agencies provide supporting services. The Department of County Engineering has a Technical Services Division that provides construction management services. These services include construction contract management, construction inspection, surveying, materials testing, and labor compliance.

As previously mentioned, the Department of District Engineering has a Water Quality Division that provides wastewater services.

The Water Quality Division, SRWTP Engineering Section is responsible for planning and design of capital improvement projects. The Engineering Section follows the project though construction as owner's representatives, and also takes the lead in documentation (e.g., plant drawings) of constructed facilities.

At the SRWTP, the O&M Section also has substantial involvement in the CIP program. While the projects are managed by the Engineering Section, the O&M Section reviews design and construction documents, assists with contractor access to operating parts of the plant, and is involved in testing and startup of new facilities. The O&M Section has a group of combined engineers and operators to perform these functions.

Several groups at the SRWTP provide construction safety. The Technical Services Division has a safety officer who focuses on construction safety. SRWTP O&M Section staff are involved in safety by providing input on issues associated with existing facilities, and the SRWTP Administration Section has a plant safety officer who is responsible for overall safety at the plant.

Significant services provided from other branches of the County and Public Works Agency include:

- Environmental Review;
- Contract Services (i.e., contracting expertise); and
- Legal Services.

SRCSD CIP History

Original construction of the SRWTP was completed in 1982. A major expansion to the plant was completed in 1992, which involved improvements throughout the plant, including influent and effluent pumping, secondary sedimentation tanks, dissolved air flotation thickening and chlorine and sulfur dioxide facilities. The next major series of expansion projects included the cryogenic oxygen generation plant, the anaerobic digesters, gravity belt thickeners, and carbonaceous oxidation tanks. Generally, all of these projects focused on expansion to meet increased flows and loads to the plant. The average annual CIP budget in the last five to seven years has been $40M per year.

Current and future major construction projects are focusing less on expansion and are becoming more driven by other factors, such as those identified below:

Regulatory Compliance: Regulatory compliance has been one factor behind the current project to provide new Emergency Storage Basins that retain wastewater when discharge to the Sacramento River is not permitted. Regulatory compliance has also driven the current biosolids dewatering project. In the past, the SRWTP has injected liquid biosolids into dedicated land disposal facilities, but lack of regulatory compliance due to groundwater impacts has contributed to the move toward biosolids dewatering and off-site biosolids recycling. Regulatory compliance due to discharge limitations to the Sacramento River is expected to be a major factor driving future projects.

Maintaining the Infrastructure: Given that the SRWTP is a relatively new plant, there have not been many major projects for rehabilitation or replacement of facilities. However, one major project is underway to rehabilitate the existing solids storage basins.

Operational Efficiencies: Historically, operational efficiencies have not driven construction projects, probably due to the age of the plant. However, a current project is complete replacement of the plant computer control system, and this project is focused on improved operations.

Safety/workplace: A current project is underway to provide new space for engineering, administration, O&M, and laboratory needs. Safety has always remained a top priority at the SRWTP; however, it has not been a major cause to construct major capital facilities.

Reclaimed Wastewater: A current project involves construction of a 5-mgd tertiary treatment facility. This will be the first attempt at off-site wastewater reuse. Larger-scale reclamation may be an important direction for the future, depending on development of regulatory and water supply issues.

Biosolids: As mentioned previously, a new biosolids dewatering facility is currently in design. Biosolids dewatering and recycling represents a new direction for the SRWTP.

SRCSD CIP Project Accounting

For the period when the benchmarked projects were in progress, the accounting system was not conducive to collection and analysis of data. Each of the projects was assigned a “facility code” that identified the specific project, and a “work authorization” which identified the funding source. Staff time sheets would list the facility code and a task code to allocate labor costs. Indirect costs were also charged to the facility code. The data could be retrieved on an accounting period or annual basis.

The facility codes are believed to have reasonably captured engineering staff time and consultant costs, but there is much uncertainty on how O&M staff actually used the facility codes. The use and definition of task codes changed during the life of the projects, and there was limited correlation between task codes and the benchmarking template. Also, use and interpretation of the task codes varied throughout the organization. Thus, the task codes were of little value. To allocate costs to the planning, design, and construction phases, it was necessary to identify dates for transition from one phase to the next and accumulate all costs hitting the projects before and after those dates.

Assignment of consultant costs to the benchmarking template was difficult. While the charges were made to the facility code, the type of work activity was not captured in the accounting system. Thus, it was necessary to make estimates of consultant charges to different phases of work in the benchmarking template. Consultant hours were not typically captured in the accounting system, making it necessary to manually estimate consultant hours from the total costs incurred.

A new accounting system is currently being developed and should be on line by July 1, 1998. The new system will greatly facilitate future benchmarking efforts.

Approach to Benchmarking Capital Engineering

Background

The capital project benchmarking effort has been conducted in three major parts:

- Process benchmarking;
- Performance benchmarking; and
- Linking performance and process benchmarking.

Process benchmarking focuses on the business processes and approaches to projects in the different wastewater agencies. The process benchmarking data is critical to being able to objectively evaluate why one agency performs differently than another.

Performance benchmarking involves development of comparative level of effort and cost data on projects between each agency. This enables determination of which agencies are more and less effective or cost efficient. It does not provide any explanation of why effort or costs are different.

Linking the process and performance benchmarking efforts is the step to determine possible reasons why one agency performs differently than another. The benchmarking team attempted to link performance and process benchmarking in several ways. The first step involved general discussion among the team to allow each team member to understand how the other agencies operate. The next step involved a more methodical approach in which involved the following steps:

- Review the performance benchmarking cost curves and categorize high- and low-cost agencies in each category (e.g., labor hours for design);
- Review process benchmarking data and identify trends between the high- and low-cost agencies; and
- Discuss the trends as a team to see if there is general agreement of the significance of the trends.

Linking the process and performance benchmarking proved to be a difficult exercise due to the wide scatter in both the process and performance benchmarking data.

Process Benchmarking

At the beginning of the benchmarking effort, the agencies met to identify the major areas of interest or common elements of work in the capital programs. The result is shown in Table 4.

Table 4 Major Areas of Interest Or Common Elements of Work.	
Process Benchmarking Topic	**Scope**
Alternative Capital Delivery	Use of non-traditional means of delivery of projects such as “design-build” and “design- build-own-operate. ”
Authority Levels	Organizational structures and responsibilities / authorities assigned at different levels.
Change Order Processing	Management and processing of change orders during construction.
CIP Development	Policies and procedures for planning and authorizing projects.
Consultant Procurement	Policies and procedures for solicitation and contracting with consultants.
Document Management	Procedures for managing construction documents including drawings, specifications, testing information, maintenance information, training information, and O&M manuals.
Partnering and Dispute Resolution	Use of partnering and dispute resolution during construction.
Project Management	Policies and procedures for management of projects.
Project Management Assessment	Assessment of the level of sophistication/maturity in an agency’s approach to project management.
Project Teams	The use of teams in capital projects including project teams, review teams and interfaces between project teams and customers.
Staffing	Approach to CIP staffing including use of consultants, organizational staffing, and basis for staffing.

Each of the above topics was assigned to one agency as the lead. The lead agency developed detailed questions, and the questions were circulated to all other agencies to provide responses. Responses were returned to the lead agency and then compiled. The lead agency also compiled summary tables and a brief narrative summary. The completed information was distributed to all agencies for review. Following the review, each agency had the opportunity to modify responses. In some cases, questions were clarified and additional questions were developed during the review process to improve the data.

The individual agency responses to the questionnaires usually represent each agency’s practices that were in effect when the projects used in the performance benchmarking portion of this study were being completed. Some of the agencies have made recent changes to work practices that may be included in these process benchmarking results.

Performance Benchmarking

Performance benchmarking compares level of effort and cost data on projects between agencies. The objective of this effort was to develop baseline design and construction management data that could be used to establish the basis for similarities or differences between agencies in the cost of project delivery.

The regional differences in labor rates for both in-house staff and consultants led the benchmarking group away from direct comparison of costs. To provide a more standardized basis for comparison, hours spent in each project phase by both in-house staff and consultants were compared with the construction costs of the projects. Only completed projects, designed and constructed in the last ten years (1987 to 1996), were included in the study. (Some projects were accepted as complete if the agency could estimate complete effort and costs for the project.)

The projects were organized as collection system and treatment plant projects. Pumping stations were classified as collection system projects. An attempt was made to organize projects for disposal/reuse and an “other” category, but there were not enough projects of this type to make this viable.

The project phase definitions (what activities were to be included in planning, design, and construction) were developed early in the study. A template for the project engineering costs and hours of effort was developed from the project phase definitions. There was considerable discussion as to how much detail to provide in the template. The differences between agencies in the accounting of project costs and financial management systems led to the presentation of cost by project phase. This was the lowest common level of possible for all of the agencies involved. Due to the differences in how agency administrative and general expenses are charged to projects, these are broken out separately.

The costs and hours of in-house staff were generally available from financial reports. The costs for consultants were available from the financial reports; however, the hours were most often estimated based on an average hourly rate because no better information was available.

The amount of the construction contract was relatively easy to obtain as well as the cost of change orders. Cost of owner procured equipment was added as an identifiable separate cost as well as hazardous materials mitigation. Hazardous materials mitigation can substantially increase the construction cost, which led to the separate accounting.

Agencies were asked to contribute data for up to ten projects for both treatment plants and collections systems. The template data was then compiled into a Microsoft Access database. The data was transferred to Microsoft Excel for the production of graphs.

The project phase definitions, a sample template, and definitions of cost categories are included in the following exhibits.

During the discussions of the results of the data, the idea of adding a rehabilitation vs. new construction index to attempt to distinguish project complexity was developed. Agencies were asked to rate all projects submitted by this index. The definition of this is also included as an exhibit.

Process Benchmarking Summary

CIP Development

The most common CIP planning or forecast period is five years. All agencies update the CIP budget annually. All agencies use long-range planning to develop the CIP budget. Long-range plans are updated at least every 10 years. Long-range planning typically ranges between 20–30 years. One agency's long-range plans extend out 50 years.

The policies for defining capital projects vary. Some agencies use a functional definition, while others use a formal capital asset or capitalization policy. The capital asset policy requires establishing a minimum dollar value. This varies among agencies. A CIP is most commonly defined as:

- A permanent improvement that increases capacity;
- An enhancement of efficiency or safety; and/or
- An extension of the useful life of the facility.

All agencies set an overall budget amount for the CIP. The customer rates, or amount of rate increase, influence the total amount of the CIP. Agency governing boards act as the final approval authority for CIP budget.

All but one agency has written instructions or guidelines to include a project in a CIP. Written instructions or guidelines vary from simply addressing cost estimating procedures to a comprehensive list of project justification topics. The most common items addressed are project description, purpose, budget, cost estimates, and schedule.

Three agencies use lists of criteria for evaluating and prioritizing proposed CIP projects. The criteria used is agency-specific, with high values placed on safety and health issues, protection of infrastructure, and regulatory compliance.

All agencies allow the staff significant responsibility and flexibility in managing individual project budgets without further governing board approval. The degree of flexibility varies between the agencies. Staffs also have discretion in determining timing of expenditures as long as approved budgets are maintained.

Partnering

The term partnering as used in this report refers to a process of identifying common goals and objectives between the agency and the construction contractor. Partnering also includes establishing a process for escalating disputes to increasingly higher levels of authority in the organization in an attempt to resolve issues while the job is in progress and avoid claims at the end of the project.

All of the agencies have used partnering (22 projects). Partnering was generally used on large-dollar projects. The minimum value of a partnered project was about $1 million. The maximum value was about $113 million.

All of the agencies have used outside facilitators. Two agencies preferred one-day meetings. Two agencies set the meeting duration based on the size of the project. Two-day meetings are common. Most agencies did not have scheduled follow-ups.

Generally, partnering eliminated confrontational interactions in meetings. It did not always eliminate posturing in correspondence, particularly as the project moved toward its conclusion. One agency noted that partnering sometimes led to a short-circuiting of communication that can cause construction management problems.

Generally, the agencies felt that partnering had a positive impact on contractor relationships. One agency said that it did not seem to have an impact on subcontractors. Another agency felt that “they were reaching saturation” with partnering and that perhaps they needed a new approach. Another agency noted that a separate partnering session for specific work items (such as testing and start-up) would be a good idea.

Partnering did not seem to have an observable impact on project schedules.

Generally, partnering did not seem to have an impact one way or the other on change orders, either in number of change orders or in their dollar value. However, partnering did appear to reduce the number of claims.

All agencies indicated that they would consider using partnering again. Most felt the partnering process could be improved.

Dispute Review Board (DRB)

There has been limited use of DRBs among the agencies. Only three of the six agencies had used a DRB on a total of five projects.

Two agencies responded that they consider using a DRB for projects that exceed $5,000,000. Another agency noted that the type of project dictates whether to set up a DRB.

Costs were available for two projects. One project with a contract value of $19,000,000 and a duration of two years had a DRB that cost $25,000. Another project with a contract value of $14,500,000 and a duration of 12 months had a cost of $48,000. Generally, the cost is split between the contractor and the agency. DRBs generally met regularly, varying from once a month to once every three months.

The presence of the DRB and the time and cost involved with case preparation tended to push both parties to compromise. This is a favorable outcome.

One agency had three items that went to the DRB and was satisfied with the process. One agency had one item and felt that the DRB was not willing to really “go out on a limb.” The DRB in this case simply made a 50/50 split.

The use of a DRB had no significant impact on contractor relationships, project schedule or change orders.

Generally the agencies felt that a DRB has its appropriate place and should be considered for certain projects. Project size and complexity are the most common factors that are considered in the use of a DRB.

Interfacing Customer Needs with O&M, Design, and Construction

The internal customer was generally identified to be the user group. The external customer was generally identified to be the rate payer.

All the agencies use project teams that include the user group (internal customer), design team staff, construction management, and consultants. One agency includes community relations personnel for certain projects. Another agency includes external customers when the project has a significant impact on the community.

All agencies involve the user groups from the planning phase through the project completion.

All the agencies have a formal design review process. The process involves review at certain predetermined levels of document completion. These levels vary slightly from agency to agency. Records are generally kept of comments and response to comments. All agencies request commitment from the user group at each phase of the design review; however no "formal commitment" is required for any of the agencies. All the agencies will make late changes to the design if the customer provides sufficient justification. Customer involvement early in design helps reduce changes. Even so, changes occur. Customers are generally not held accountable for changing their minds.

Only one agency has a formal customer survey. Generally, there was a feeling that it is difficult to meet all customer expectations. Four of six agencies felt they met most of their customer needs.

Most agencies identified the project manager as the person with first-line budget responsibility.

All agencies make changes that are necessary for the proper operation of the project. Four agencies try to incorporate enhancements where possible. Two agencies have a more rigorous process for making enhancement changes that are requested by the user groups.

Equipment Records, As-builts, Testing, Operation Training, Warranty and O& M Manuals

All six agencies have some form of a master equipment list as their maintenance management system. All agencies assign equipment numbers to equipment. A master equipment list typically includes an equipment number, location, description, and maintenance history information. Most agencies maintain a master drawing list for contract drawings.

Generally, the contractor is required to maintain "as-built" (record drawing) documentation during the construction period. The construction management team is responsible for reviewing this documentation. Final drafting onto the record drawing is usually performed by agency staff or outside drafting services. Contract (construction) drawings are the only as-built drawings kept and/or maintained by all agencies. All agencies use the construction drawings to reflect actual field conditions. One agency confirms as-built documentation for all shop drawings. Another agency confirms electrical and instrumentation shop drawings in addition to the contract drawings. As-built documents are archived by all agencies.

Conformed plans and specifications with addenda are normally issued by the agencies. One agency does not issue conformed documents.

At four agencies, the designer, with assistance from agency staff, develops the test plan for the bid documents. At two agencies, the contractor, using the contract specifications as a guide, develops the test plan. Generally, the test plan includes parameters for performance, acceptance, tests to be performed, and records to be maintained. Test plans are usually established for equipment, mechanical, electrical, and instrumentation systems. The test plan is part of the contract specifications for all but one agency. The contractor usually performs the initial testing. At one agency, the construction management team conducts all testing. Testing records are maintain and usually included in the O&M manuals.

All agencies have an operation training period or session for new or unfamiliar equipment/systems. Generally, the contractor and/or the equipment vendor provide the training and training documentation.

Warranty starts at acceptance of equipment or facility. Usually, the O&M staff provide the vendor notification, although at two agencies, vendor notification is done through the construction management team.

The design consultant prepares facility O&M manuals for all but one agency. One agency prepares its own O&M manuals. The construction contractor, equipment manufacturer, or product vendor produces product O&M manuals. All agencies verify the completeness of product O& M manuals. Most agencies are moving into an electronic format for O&Ms. Product O&M manuals are distributed to the O&M sections for all agencies. Only three out of the six agencies update the product O&M manuals.

Authority Levels

General

Excluding the governing board, most agencies have roughly six levels of authority. These levels range from an engineering support staff to upper management. Titles and positions vary among the agencies. Senior Engineers and above are typically considered to be upper-level engineers.

Most agencies require all but junior or assistant-level engineers to be licensed.

Purchasing limits vary widely among the agencies. Most agencies have a $2,500 limit for mid-level engineers. Managers generally have a limit of $10,000–$35,000. Two agencies have an upper-level management limit of $100,000.

Design

Decisions on control system, process design and equipment selection are usually made by the Project Manager, who is typically a mid-level engineer. Control system and equipment selection decisions for one agency are made at the management level.

All agencies have the design documents reviewed by members of the project team and the primary stakeholders. This usually consists of the design team, construction management group, and O&M personnel. All agencies require the signature of an upper-level engineer on the contract documents.

For all agencies, the cost estimate for a project is handled by the project manager, who is typically a mid-level engineer. Upper-level engineers review the cost estimate for all agencies. On major projects, the engineering consultant involved in the design usually does the actual estimate.

Construction

For most agencies, the construction project manager makes the decision with input from design and/or operations. Criteria used to make this decision include budget, scheduling, and justification. The construction management team issues field instructions for all agencies.

Most agencies have a written manual that delineates the roles and responsibility of the project team. The preconstruction meeting is the forum where these roles and responsibilities are conveyed to the contractor. Generally, project inspectors have responsibility for ensuring compliance with plans and specifications, the construction manager has responsibility for contract administration, and design issues reside with the designer.

The construction management team has responsibility for interpreting plans and specifications for all agencies.

For all agencies, the review of contractor claims is the responsibility of the construction management team. This review initially consists of determining entitlement. If entitlement is established, the construction management team has the responsibility to negotiate an equitable adjustment.

Planning

Master planning generally involves the expenditure of CIP funds and requires a “big-picture” view. For all agencies, these decisions and recommendations are made by upper management and approved by the governing board.

Regulatory issues are generally the responsibility of the mid- to upper-level engineers. Two agencies have a regulatory compliance office that address regulatory issues.

The authority to negotiate permits and discharge agreements resides with upper-level management for all agencies. Initial negotiations and tentative agreements are often done by mid-level engineers prior to execution by upper-level management.

Operations

All agencies go to great efforts in the planning and design phase of a project to try to ensure that construction has minimal effect on plant operations and vice versa. All indicated that close coordination and communication is necessary to meet this goal. If a decision needs to be made on whether an operation or construction matter should take priority, this decision is made by the plant and/or operations manager.

Most agencies indicated that process testing involves both the operations and the construction management groups. The construction management group has responsibility for ensuring contractor compliance with the project documents. The operations group has responsibility to ensure that the facility fully functions as intended. One agency has the construction and management group responsible for startup and testing, while the operations group is responsible for commissioning.

For all agencies, approval to access plant equipment or an active plant operational area lies with the operations group or operations coordinator.

Change Order Processing

All six participating agencies have a formalized change order process that requires some review and approval of change orders prior to their execution. The authority to approve change orders for three agencies varies based on the value, appropriation limit, or type of change. Authority to approve change orders for these agencies can be delegated to lower levels in the organization. Change orders for the three other agencies must be approved at the highest level of the organization: the board or department director. These agencies are planning to seek delegation of authority to approve change orders in future.

In general, the amount of documentation required for a change order is most detailed for the three agencies that require board or director approval for change orders. Change order documentation is generally a stand-alone package that describes in detail the change, including all related paperwork as well as a justification for the change.

The time to secure approval of a change order varies between a few days to two or three months. Again, those agencies that delegate change order approval on average have the fastest approval times. Change orders normally are approved after the work has been completed.

Two agencies set aside specific percentages of the contract bid amount for change order work. One agency has established percentages as guidelines based on the type of construction, with higher percentages for smaller contracts and renovation work. Three agencies do not formally set aside funds for change order work.

Consultant Procurement

The consultant procurement process generally includes, for all six agencies, the following:

- Request for Qualifications/Request for Proposals (separately or combined);
- Evaluation of proposals by a selection committee;
- Potential interviews with selected consultants;
- Recommended selection of a consultant;
- Negotiation of the contract; and
- Award of the contract.

The consultant procurement process can take from two to seven months to complete. Five agencies have streamlined consultant procurement processes for contracts under a threshold limit. Each agency has established its own limits, which vary widely. The five agencies that have streamlined their procurement process indicated limits of under $18,000, $20,000, $50,000, $100,000 and $150,000. These streamlined procurements average from two weeks up to four months.

Selection committees are generally comprised of internal staff and managers. However, two agencies did report that they typically include a member outside the internal staff to participate in the selection process.

Contracts are usually negotiated by the project manager and executed by a formal board or department director. Four agencies have delegated authority to execute consultant contracts at lower levels based on contract value, typically between $20,000 and $50,000.

Standard selection criteria exist for evaluating consultant proposals, but generally are modified to meet project needs. Four agencies include M/WBE considerations as either selection criteria or set goals for the contract.

Documenting the process involves maintaining copies of consultant submittals (SOQs, proposals, etc.), reviewer rating sheets, recommendation memos, negotiation records, and the contract.

Staff Utilization

All agencies indicated that house staff are considered and often used for smaller, less-complex projects. None of the agencies indicated that in-house staff is never used. Consultant staffs are generally used for the larger, more complex projects. The agencies indicted that this practice was based more on staff availability than staff ability. If consultants are utilized, they generally perform the entire design, as opposed to a design team comprised of agency and consultant staff.

Most agencies use both in-house staff and consultant staff for construction management. One agency uses all in-house staff. Agencies that use consultant staff usually have a construction management team of staff blended from both in-house and consultant staff. The decision to use consultant staff is generally based on availability and expertise of in-house staff.

For all agencies the capital improvement program projections govern the agencies' core staff levels. These projections vary from one to five years. Consultant staffs are utilized to augment peak demands. All agencies indicated that staffing needs are sensitive, political, and closely scrutinized.

The ratio of managers to staff ranged 1:14–1:30. The ratio of supervisors to staff ranged from 1:4 -1:12.

Construction Contract Approval and Award

The dollar amount at which a competitive bid is required for a project varies by state and by agency or governing body within the state. All agencies required that contracts over $100,000 be competitively bid. One agency required contracts over $10,000 to be competitively bid. Generally, the threshold at which competitive bids were required was between $25,000 and $50,000.

Generally minimum bid periods of 10–30 days have been established by the agencies. Large or complex projects usually have longer bid periods.

With the exception of one agency, the governing board approves the contract. For one agency, the department soliciting the contract makes the approval of the contract.

Most agencies have MBE/WBE goals or strongly encourage the use of MBE/WBE firms.

Generally, the transfer of a project from design staff to construction staff occurs after award and approval of the contract. Two agencies transfer the project to construction staff at the time the project is advertised.

Project Management

Project management was assessed using two different questionnaires. One contained seven questions related to project management policies and procedures.

The other questionnaire contained approximately 70 questions and was taken from a Project Management Assessment conducted by The University of California at Berkeley and the Project Management Institute (Berkeley/PMI). There were six areas of project management process assessed with this tool:

- Project initiation;
- Project definition;
- Planning the project;
- Tracking and managing the project;
- Closing out the project; and
- Organizational environment.

The scores represent the organization maturity in the particular area of project management. The higher the score, the more efficient the organization is in its project management. The results for the agencies are compared against the results of the Berkeley/PMI study group of private and public firms.

All agencies have manuals that describe procedures for managing design and construction projects in the organization. Some agencies have separate manuals for each project phase, while other agencies have one manual that addresses project phases or specific items (such as CEQA). Maintenance of the manuals is typically the responsibility of the engineering departments. Changes to manuals are issued in memo format signed by the engineering manager and distributed to all project managers for insertion in their assigned manual. There is no pattern among agencies as to when manuals are updated.

Berkeley/PMI Maturity Assessment

Three agencies had an average score similar to the Berkeley/PMI average. Three agencies scored lower than the Berkeley/PMI average because:

- They do not prepare a project initiation checklist; or
- They only get informal commitments from project team members.

Project Definition: All agencies except one scored high in the area of project definition. Three agencies exceeded the Berkeley/PMI average score. The reason for the one agency's low score is:

- The project team is not formalized by a project organization chart with defined roles and responsibilities; and
- Alternative strategies are not evaluated or planned.

Planning the Project: Only two agencies scored higher than the Berkeley/PMI average in planning the project, while three agencies scored significantly lower than the other agencies. Reasons for low scores include:

- Options for trading off scope, schedule, and budget are evaluated by the project manager and not the entire project team;
- They tend not to gain management agreement on project changes;
- They do not have formal processes for evaluating project risks;

- Project cost estimates are typically not on file and are not agreed to by all involved parties; and
- Project priorities are not evaluated and agreed to by the project team.

Tracking and Managing the Project: Only two agencies scored higher that the Berkeley/PMI average in tracking and managing the project, while two agencies scored significantly lower than the other agencies. Lower scores are attributed to:

- They do not document and track variances in scope, schedule and budget;
- They do not analyze impacts of variances; and
- They tend not to determine the root cause of variances or develop plans to address them.

Closing Out the Project: All of the three agencies scored better than the Berkeley/PMI group average in closing out the project, while two agencies scored significantly lower than the other agencies. Agencies with lower scores:

- Do not formally ensure that deliverables are completed;
- Do not always complete remaining close out tasks;
- Do not have a good process for reviewing key technical lessons; and
- Do not evaluate the project management process.

Project Organizational Environment: All agencies scored close to the Berkeley/PMI average in project organizational environment. Two agencies scored much higher than the others did. Items which the higher scoring agencies did to make a difference include:

- Offer monetary and non-monetary rewards to project team;
- Have detailed budgeting and cost management systems in place; and
- Create project relationships with suppliers.

Alternative Capital Delivery

There is limited experience in the use of alternative capital delivery, but it has been applied in a wide range of types and sizes of projects. Five of the agencies have used alternative approaches on a limited basis. Four agencies have limited experience with design-build. Two agencies have attempted a design-build-own-operate arrangement. One project was a biosolids pellatizing facility and the other was a biosolids dewatering facility.

Overall, the agencies lack policy decisions and standardized procedures for alternative capital delivery projects. Only one agency had a formalized checklist for reviewing the applicability of alternative capital delivery. Some agencies are limited by state law that prohibits design-build projects.

Cost and time savings are the most common reasons for the use of alternative capital delivery and, in general, the projects have been successful in these areas. The need for proprietary products was also cited more than once.

There have been a wide variety of problems, including lack of contractor design and regulatory capabilities, lack of contractor responsiveness to agency needs, maintenance responsibilities during operating phases, and inability to meet performance requirements. Problems in selection of contractors and negotiating contracts have also occurred. Successes have included competitive pricing and timesavings.

Inspector Duties

Inspection and Monitoring of Contract Work

All agencies require their inspectors to perform the following core inspection duties:

- Observe field installation of work shown on contract drawings, in the specifications, and in other contract documents (such as submittals, RFIs, Clarification Notifications (CNs), Field Instructions (FIs), and other formal correspondence) affecting scope, cost, and schedule of the work.
- Thoroughly understand all requirements of the work progressing in the field, including keeping updated plans and applicable submittals in possession at all times.
- Notify the project manager (in a timely manner) of any observed unauthorized deviations, non-compliance, unsatisfactory workmanship, unsafe operations, etc. that might adversely affect the project quality, system operation, or schedule.
- Prepare punchlists and maintain a log showing status.

Most agencies require that the inspectors be very familiar with the contractor's schedule and identify (via daily diaries and weekly team meetings) critical path activities that are and are not being worked on or are being performed out of sequence.

All agencies require their inspectors to:

- Be familiar with aspects of the project that need coordination;
- Interact as necessary with inspectors of the other disciplines; and
- Interact with plant operations personnel to coordinate system shutdowns and tie-ins.

As part of the project documentation, all agencies require their inspectors to:

- Maintain personal plans and specifications that reflect the latest up-to-date information such as RFIs, submittals, FIs, CNs, and other formal correspondence;
- Provide input into the as-built process; and
- Note elevations that deviate or routing of pipes which differs from the contract drawings, etc. This information is to be documented on full-size plans that are kept in the project team area.

Daily Diaries

All agencies require their inspectors to prepare a daily diary that describes the work in sufficient detail to provide a record that will stand alone as a definitive statement of the contractor's activities when read by a third party. Diaries for all agencies typically include an accurate and detailed description of:

- The work performed: How much, what size, from where to where, what system, when started, when stopped, when suspended, when completed, and when tie-ins to existing systems were made;
- The weather (both a.m. and p.m.);

- Any safety issues;
- Rework performed and why, including estimate of hours observed and materials used;
- Corrective work performed;
- Equipment or materials delivered or set in place;
- Any tests taken and their results (e.g., compaction tests, pressure tests, electrical tests);
- Any equipment in operation or idled and why. (e.g., mechanical failure, not needed);
- Any extra work or disputed work performed;
- Extra work or disputed work;
- Substantive conversations held with contractor's foremen as well as any commitments made by either party;
- Any work or material in place that does not correspond with the drawings or specifications as well as action taken. Issue non-compliance notices (NCN) as necessary;
- Follow-up inspections of previously reported deficiencies (NCNs); and
- Daily labor compliance data such as: hours, trade, classification, task and schedule activity number.

Diaries generally are to be completed at the end of the work day.

All inspectors take photos periodically to show progress and other special circumstances.

Testing

All agencies have their inspectors describe any tests taken and their results (e.g., compaction, pressure, electrical) in their daily diaries, coordinate tests performed by the materials lab (and surveying), and to witness performance tests.

Inspectors for three agencies cast concrete cylinders and perform slump tests when needed.

Safety

All agencies require inspectors to note any safety observations, issues, or accidents in their diaries and to attend a requisite number of safety meetings and update their knowledge of Construction Safety Orders, General Industry Safety Orders, and agency policies.

Labor Compliance

Inspectors for two agencies perform monthly labor compliance interviews with contractor and sub-contractor employees.

Performance Benchmarking Summary

Each agency in the study was requested to provide cost information on 10–12 capital projects that had been completed within the past five years. Projects that were almost complete and for which final costs could be estimated were also allowed. Each agency supplied the information on the performance benchmarking templates described above. A group consensus was reached on how to display the data in graphical form, once all the data had been gathered. The resultant group consensus resulted in the following list of graphs:

- Planning Hours vs. Construction Costs;
- Design Hours vs. Construction Costs;
- Construction Management Hours vs. Construction Costs;
- Total Project Hours vs. Construction Costs;
- Change Order Percent vs. Construction Costs;
- Rates of Consultant to In-House Engineers vs. Construction Costs;
- Number of FTEs vs. Construction Costs; and
- Design Cost/Construction Cost vs. Change Order Percent.

Other presentations of the data were discussed and examined, but were discarded either due to lack of data from the agencies’ records or because no significant conclusion could be drawn from the plots.

Linking Process and Performance Benchmarking

This chapter is divided into two sections. The first section provides a discussion on observations made from review of the performance benchmarking graphs. The second section discusses possible causes for performance.

The benchmarking team recognized that the data used in this study has significant value in helping to focus improvement efforts for each contributing agency, but the data does have significant limitations. In some cases, trends are counterintuitive, leading to suspicion of the validity of the data, and there is reason to believe that the data may not have been consistently applied from all agencies due to accounting and management systems.

Caution must also be exercised in making judgements on individual aspects of capital improvement programs. The benchmarking team recognizes that individual differences between agencies may result in different impacts on overall performance, depending on the overall systems of the agencies. Thus, the data and interpretations presented herein must be used to stimulate thought process among the individual agencies, and must not be used as definitive “best practices.”

General Observations from Performance Benchmarking Graphs

Following is an assessment of trends from the performance benchmarking graphs. For plant work, there is little data above $25 million in construction cost. Curves should not be extended beyond that point, since there is no data to substantiate them.

Planning Hours Versus Construction Cost

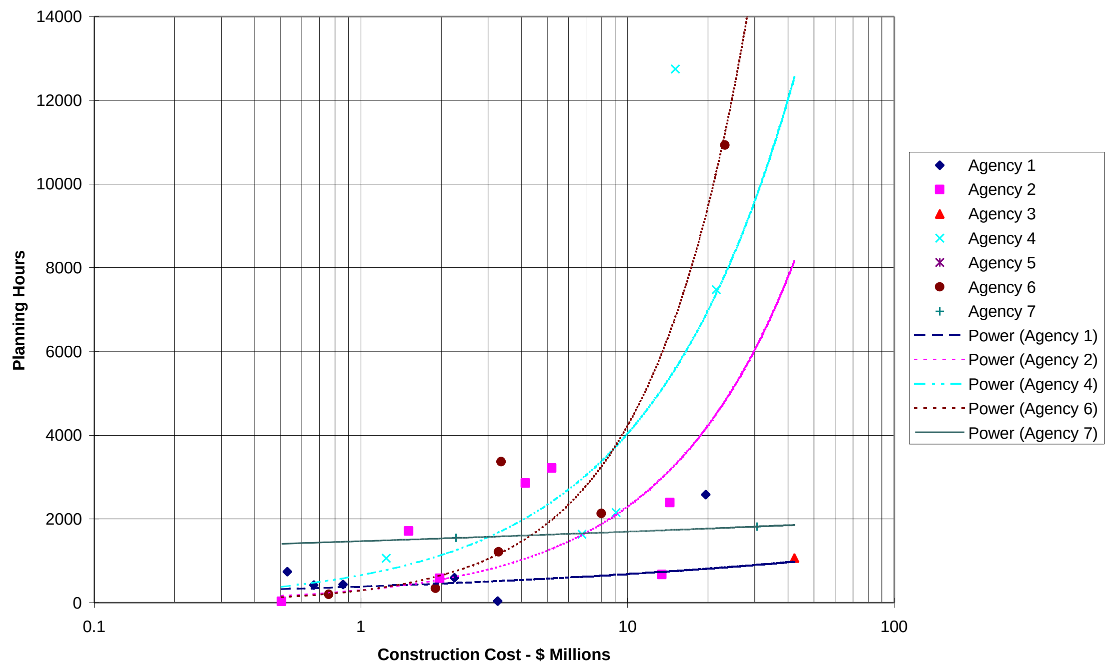
One agency did not have sufficient cost information on planning costs to develop an adequate set of data points.

For plant work, three agencies spend more planning hours of construction cost as the construction costs increase. The other two agencies spend less than 2,000 hours regardless of the total construction cost of the project.

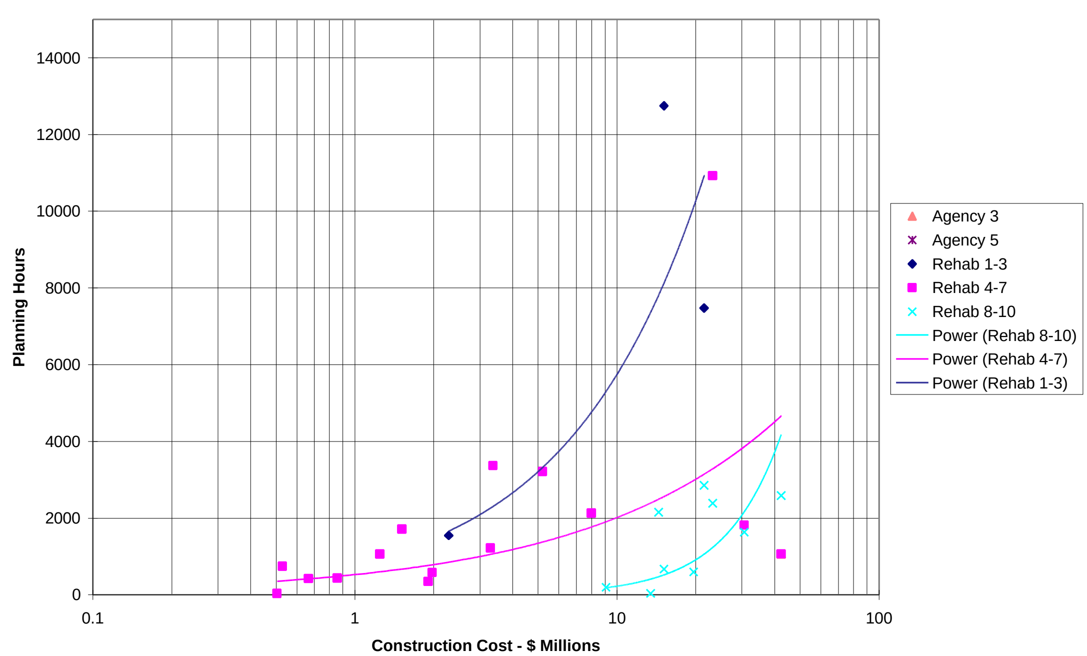
Generally, it appears less time is spent on planning for collection system projects. For collection system work, two agencies spend more planning time as the cost of the construction increases. The other three spend less than 1,000 hours on planning, regardless of the cost of the project. Comprehensive planning work not associated with individual projects has not been included in the cost data. Much of the planning work for some agencies is done on a regional basis.

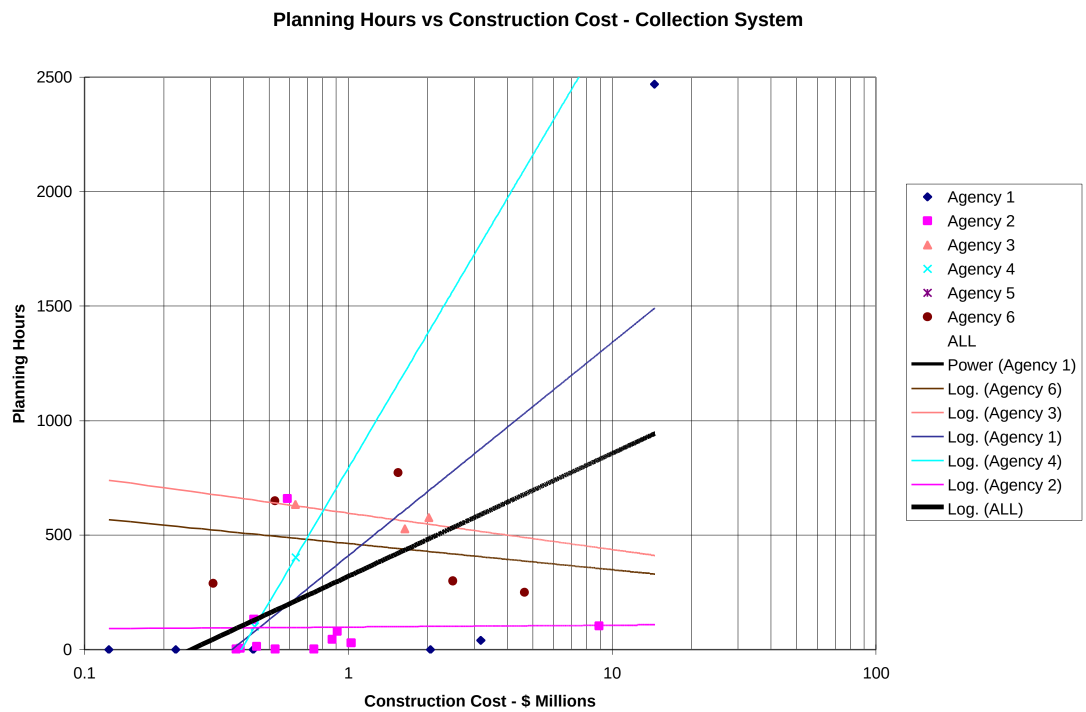
From the Rehab versus New curves, it looks like the more complex the plant project, the less planning hours spent. The collection system graph does not show much of anything.

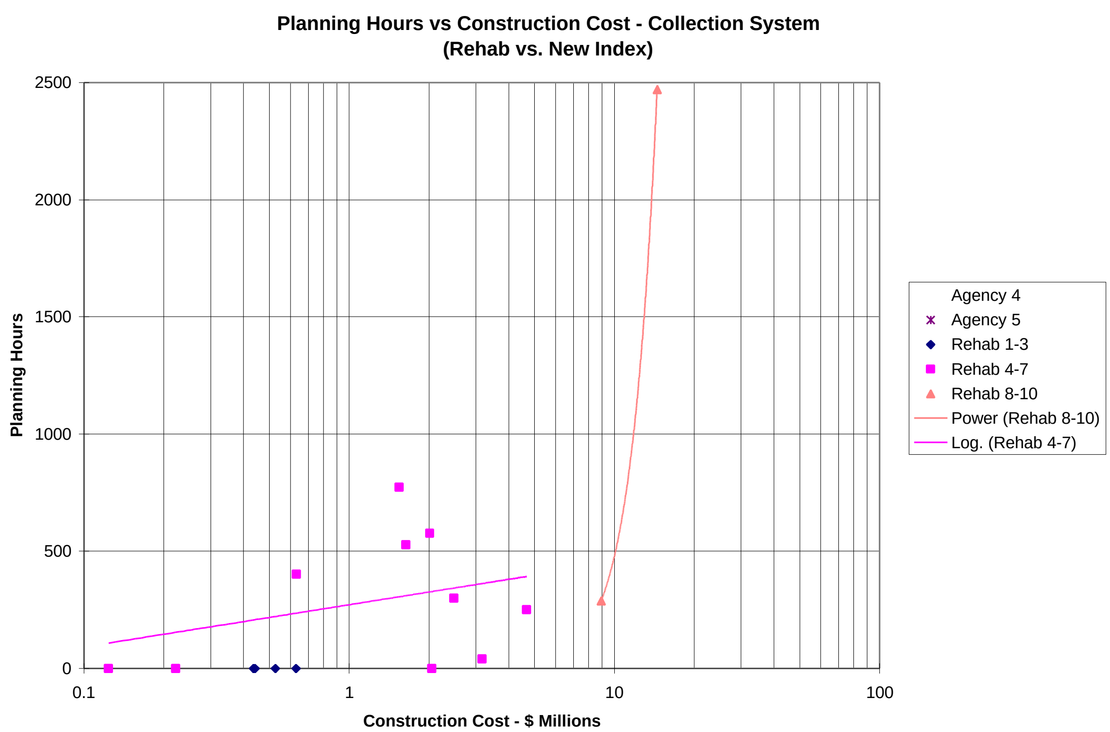
Planning Hours vs Construction Cost - Plant



Planning Hours vs Construction Cost - Plant



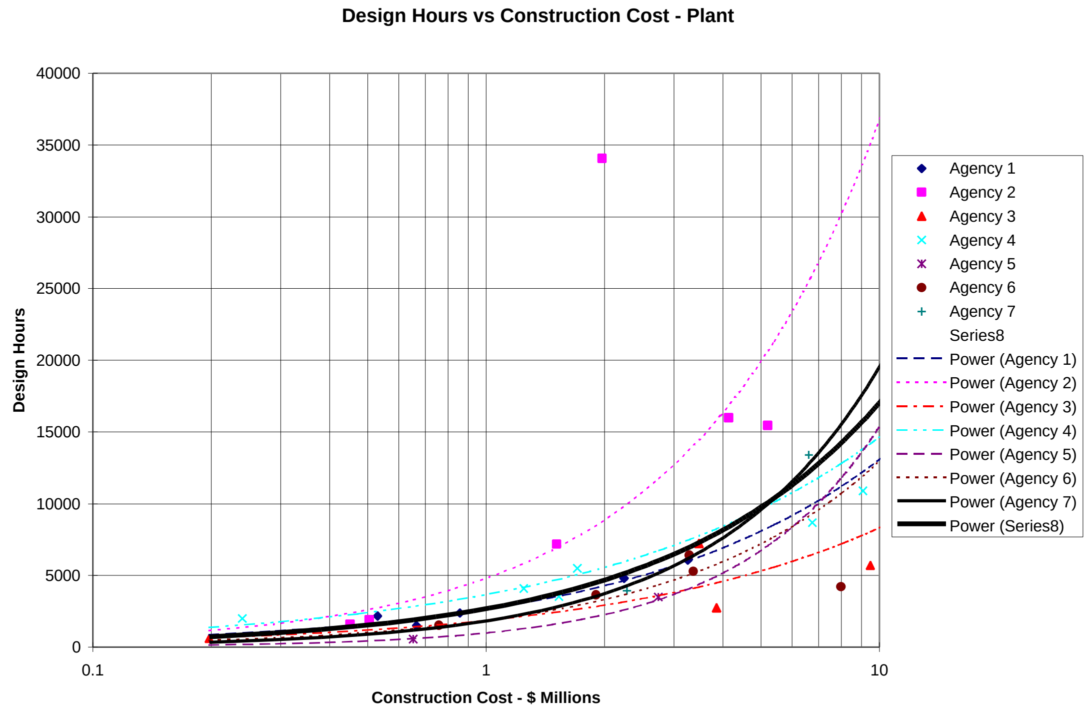

Planning Hours vs Construction Cost - Collection System
Planning Hours
2500
2000
1500
1000
500
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Log. (Agency 6)
Log. (Agency 3)
Log. (Agency 1)
Log. (Agency 4)
Log. (Agency 2)
Log. (ALL)


Planning Hours vs Construction Cost - Collection System
(Rehab vs. New Index)
Planning Hours
2500
2000
1500
1000
500
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 4
Agency 5
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 8-10)
Log. (Rehab 4-7)

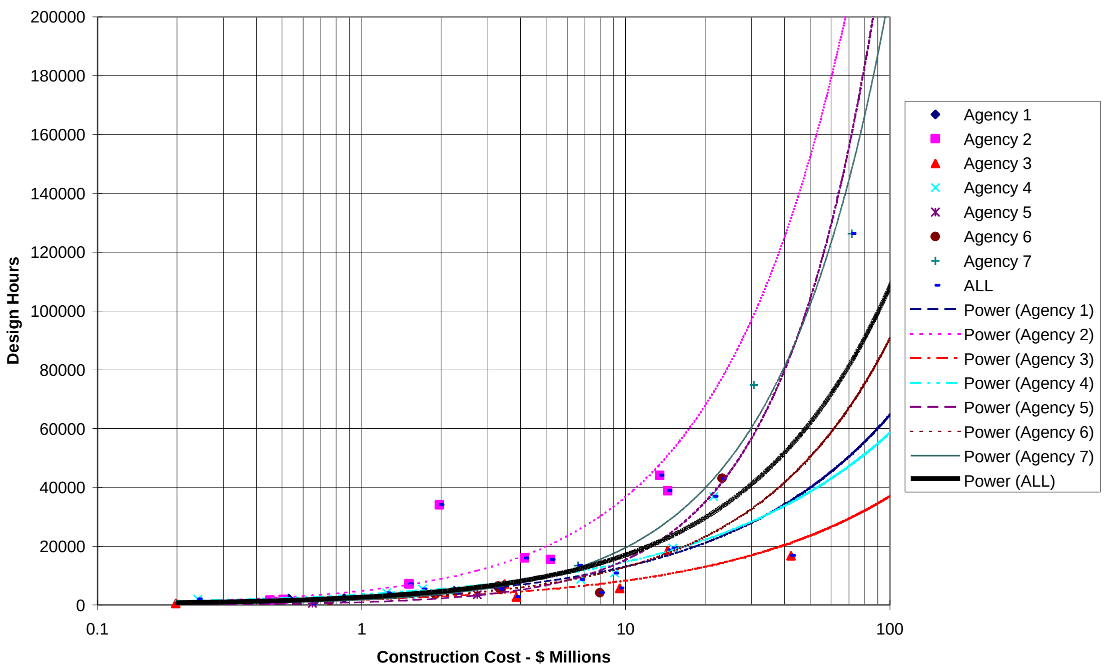
Design Hours Versus Construction Cost

Average design hours per million of construction cost is similar for collection system and plant work. (This trend is similar to construction management phase of the project.) However, the statistical analysis indicates that there is more variability for collection systems than for plant work. This variability may be attributed to inclusion of collection system pump station and pipeline projects in the same data base. There is a wide spread between agencies for both collection and plant curves, particularly as the construction cost approaches $10 million.

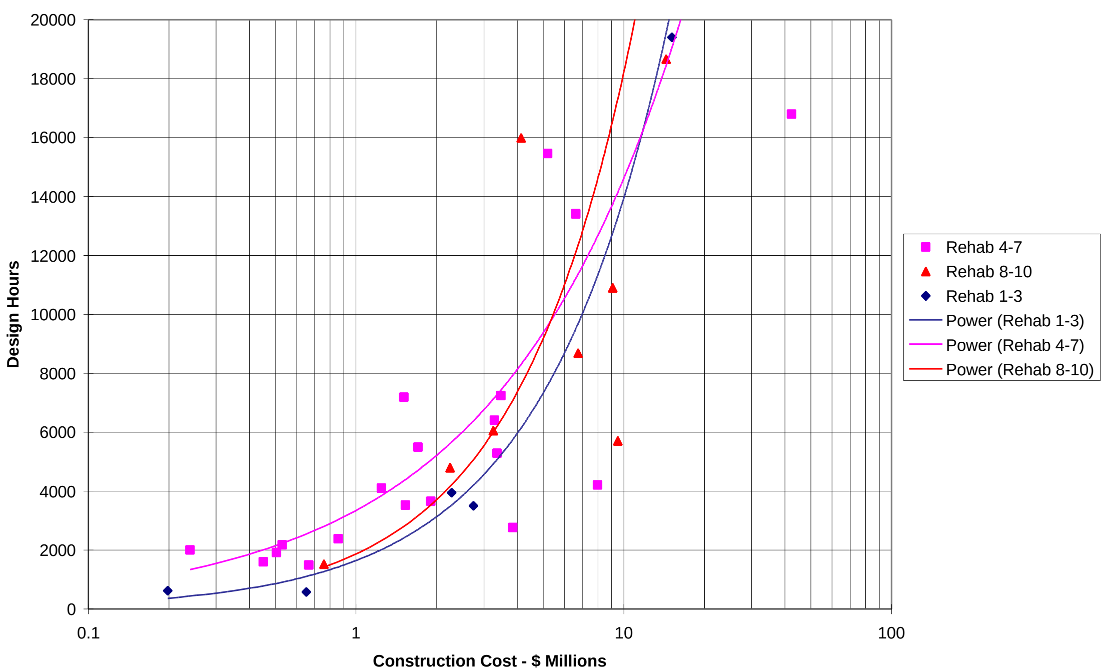
The rehab versus new curves for design hours reflects similar trends in CM hours, and it appears that design effort is not affected much by the complexity of the project for plant work. There is more variability in the collection system curves for design effort.

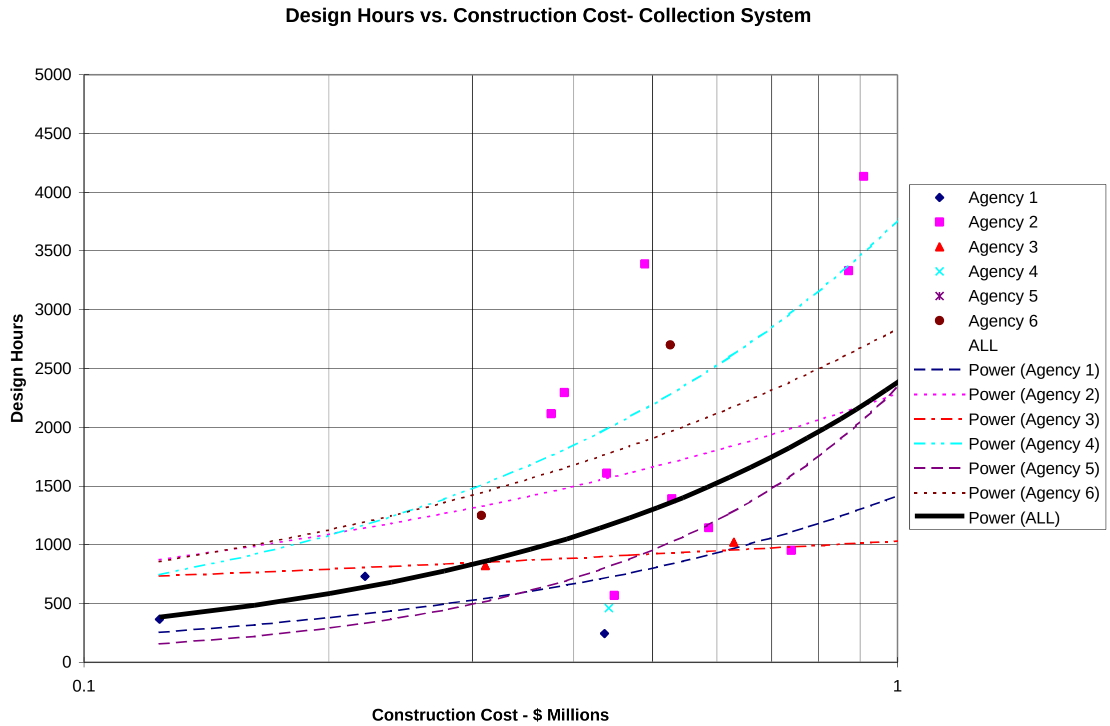


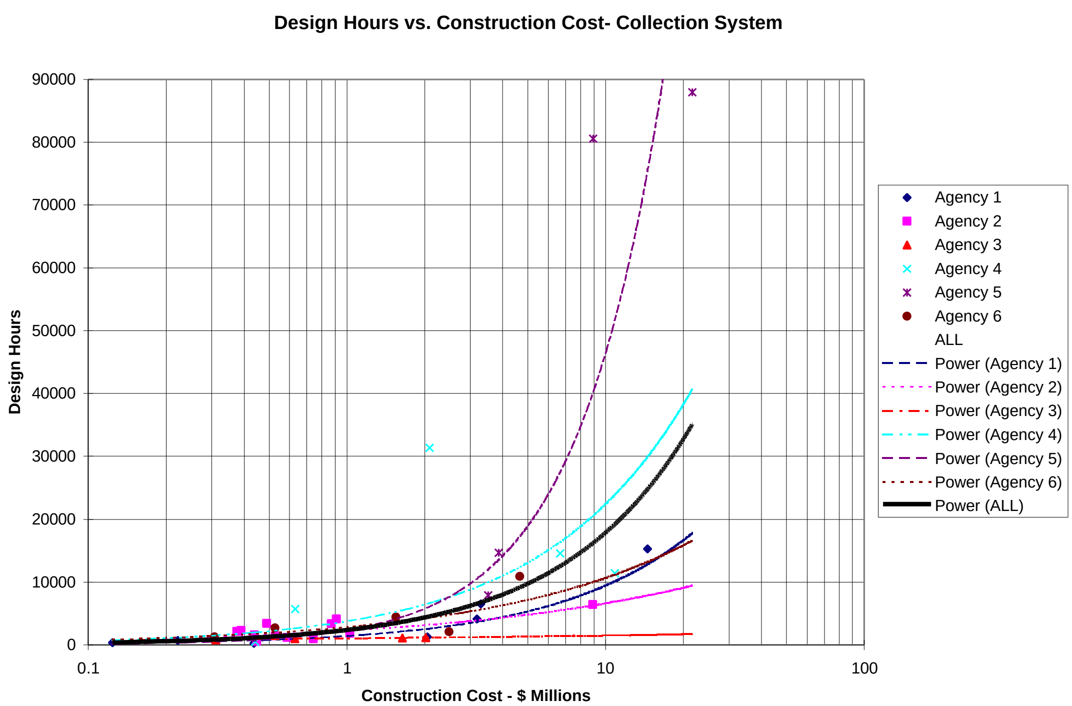
Design Hours vs Construction Cost - Plant

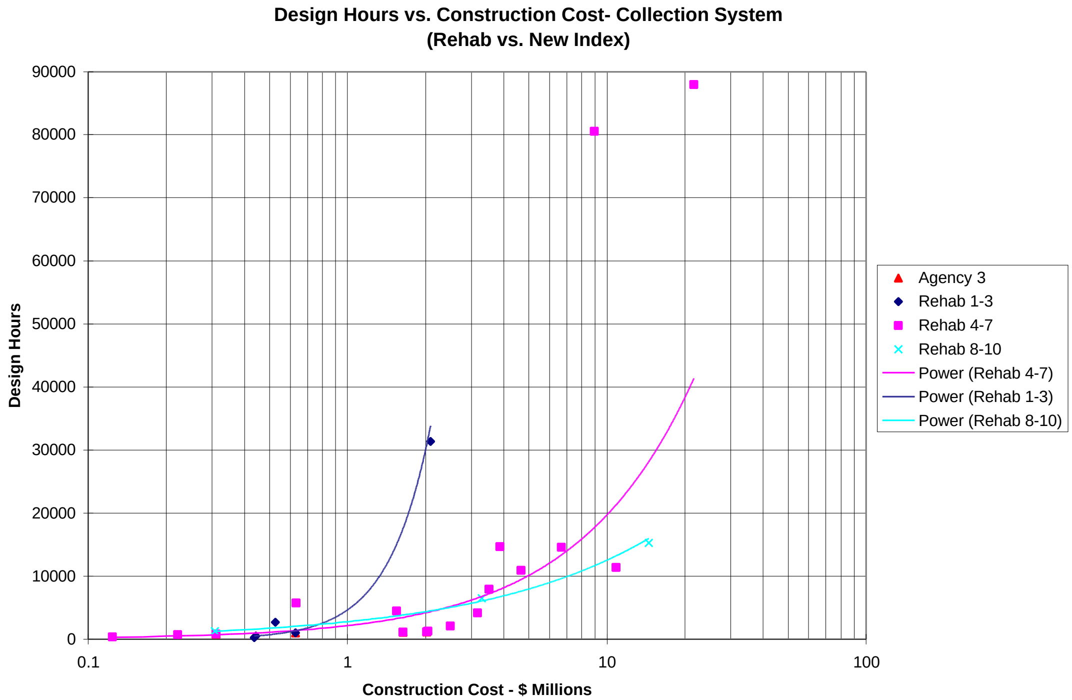


Design Hours vs Construction Cost - Plant
(Rehab vs. New Index)




Design Hours vs. Construction Cost- Collection System
Design Hours
Construction Cost - $ Millions
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.1
1
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (ALL)

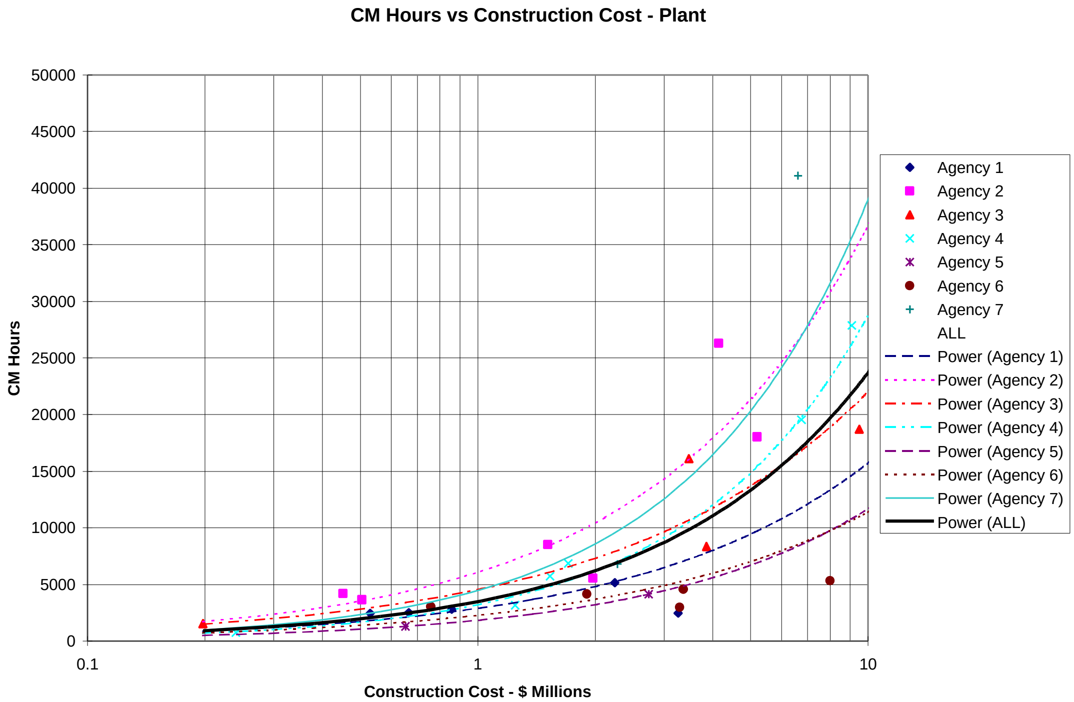

Design Hours vs. Construction Cost- Collection System
Design Hours
Construction Cost - $ Millions
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0.1
1
10
100
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (ALL)

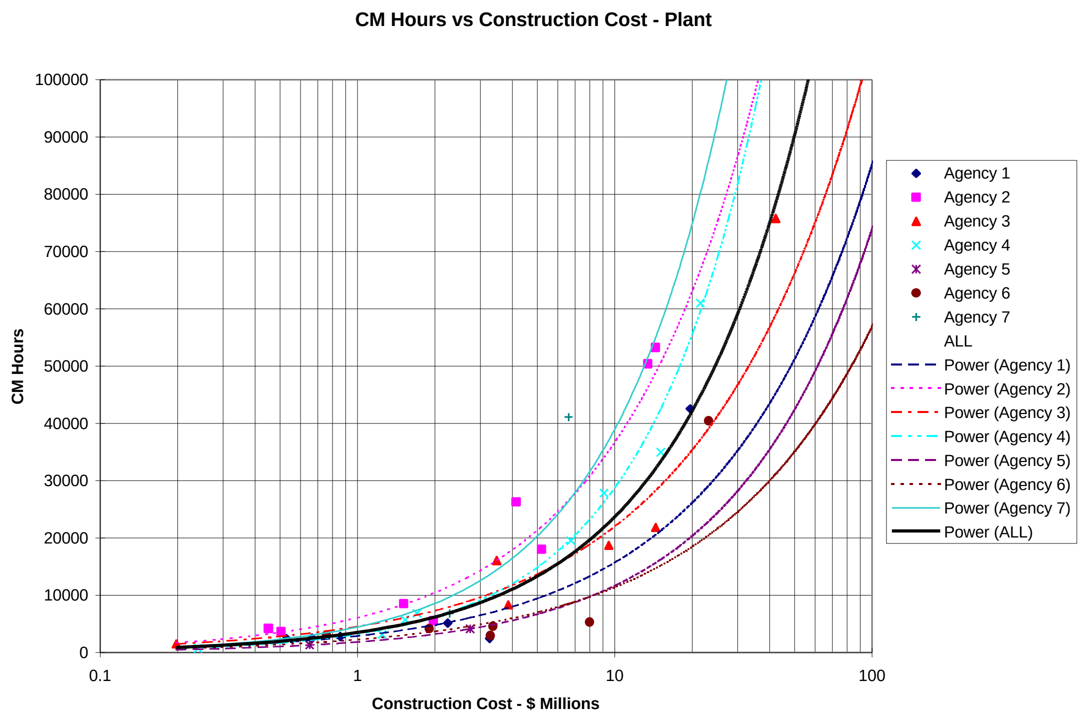

Design Hours vs. Construction Cost- Collection System
(Rehab vs. New Index)
Design Hours
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 3
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 4-7)
Power (Rehab 1-3)
Power (Rehab 8-10)

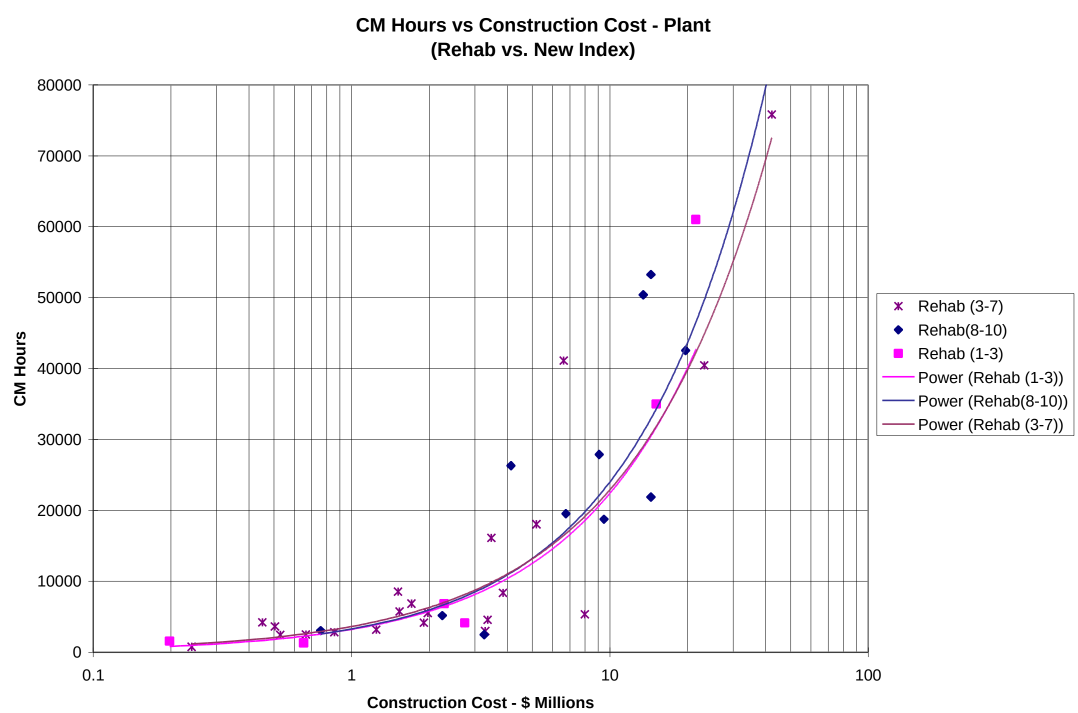
Construction Management Hours Versus Construction Costs

The shape of the average curve for the collection system and plant charts is very similar (comparing CM hours for the $1 million and $10 million axis points). This would seem to indicate that CM hours required per million of plant or collection system work should be the same on average. However, there is a wider spread among the agencies for CM hours required for plant work. At the $10 million axis point, the low value is 11,000 hours per million, and the high value is 40,000 hours per million for CM support. For collection system work, at the $10 million axis point, the low value is 13,000 hours per million and the high value is 30,000 million.

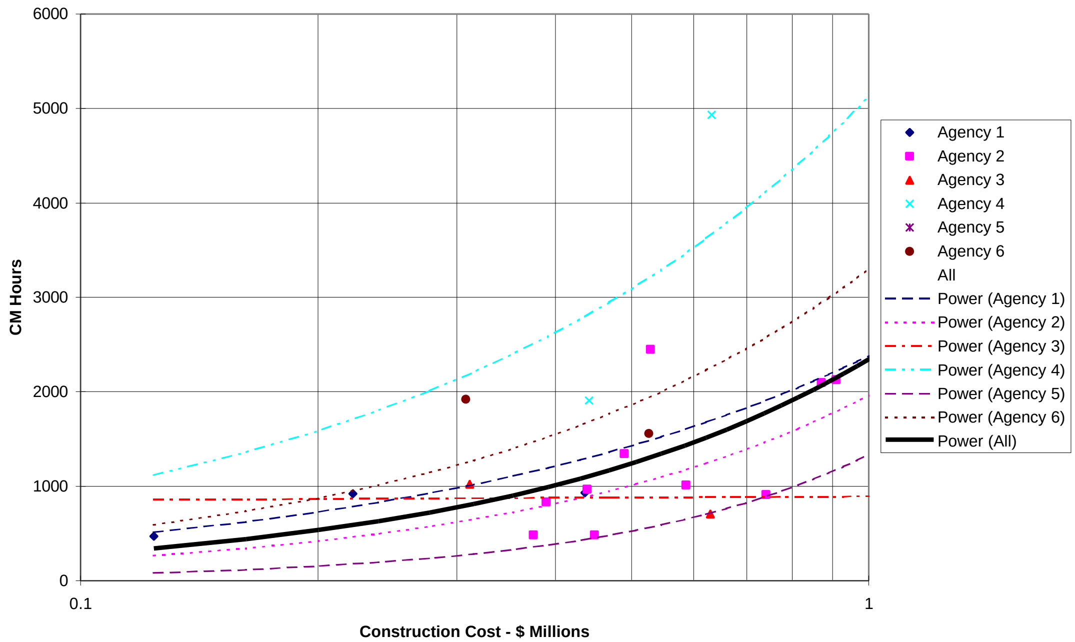
The rehab versus new curves for plant projects are almost the same, indicating the CM effort is not affected by whether the project is new or a complex rehabilitation. The rehab versus new curves for collection system projects are also very close, leading to the same conclusion. The lack of data points for the Rehab 8-10 category may skew the curve.



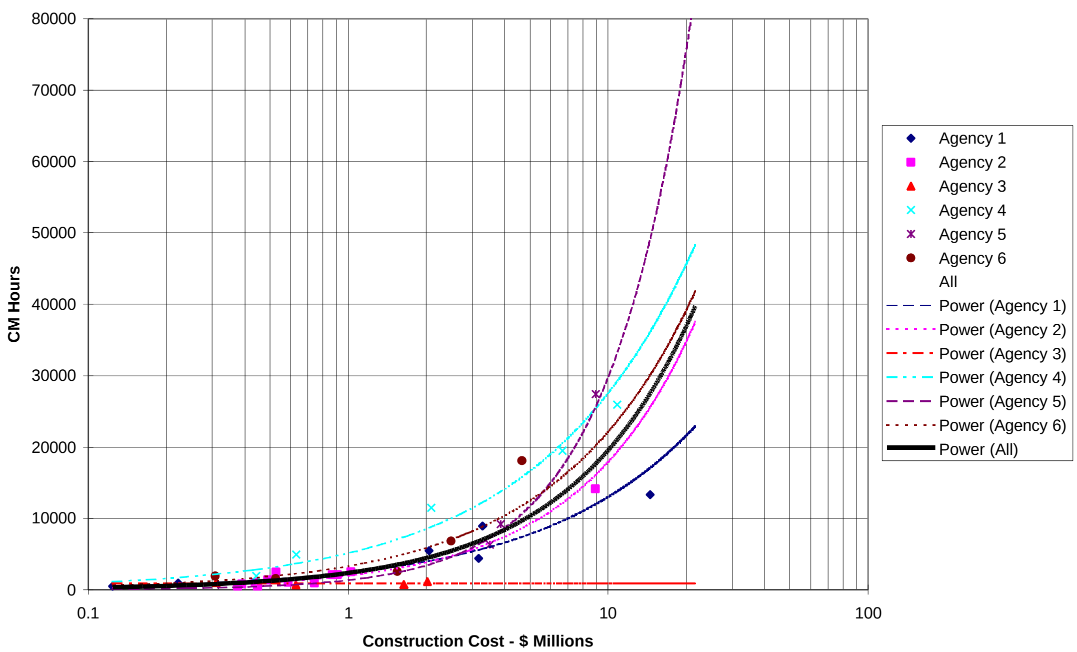

CM Hours vs Construction Cost - Plant
CM Hours
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
Agency 7
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (Agency 7)
Power (ALL)

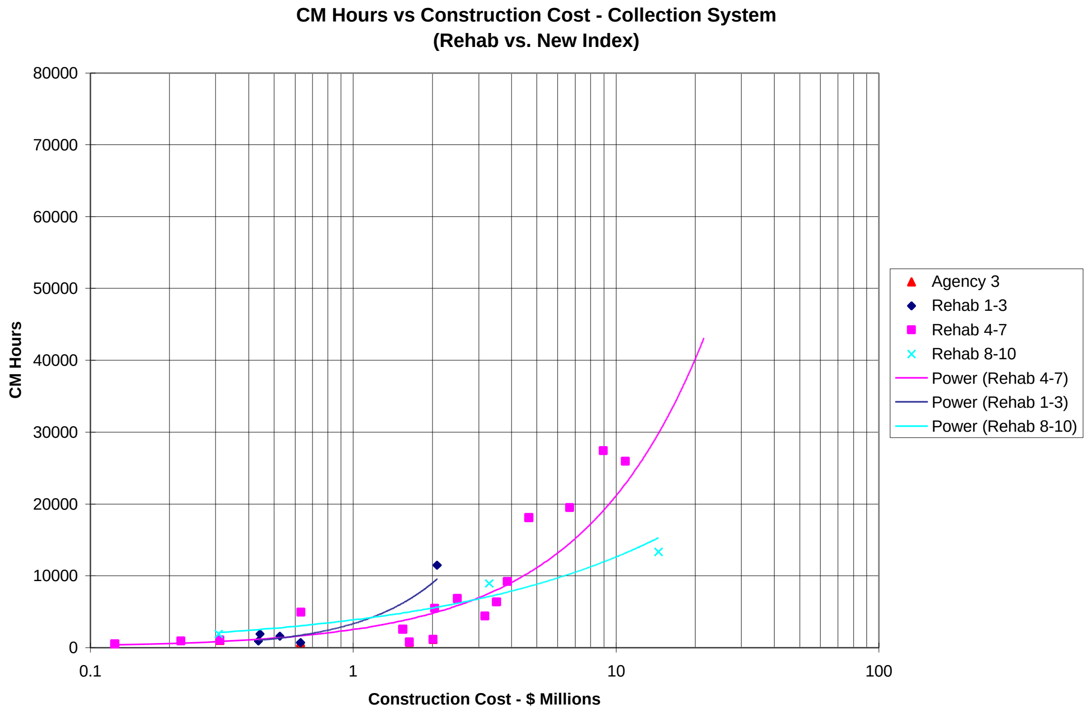

CM Hours vs Construction Cost - Plant
(Rehab vs. New Index)
CM Hours
80000
70000
60000
50000
40000
30000
20000
10000
0
0.1
1
10
100
Construction Cost - $ Millions
Rehab (3-7)
Rehab(8-10)
Rehab (1-3)
Power (Rehab (1-3))
Power (Rehab(8-10))
Power (Rehab (3-7))

CM Hours vs Construction Cost - Collection System



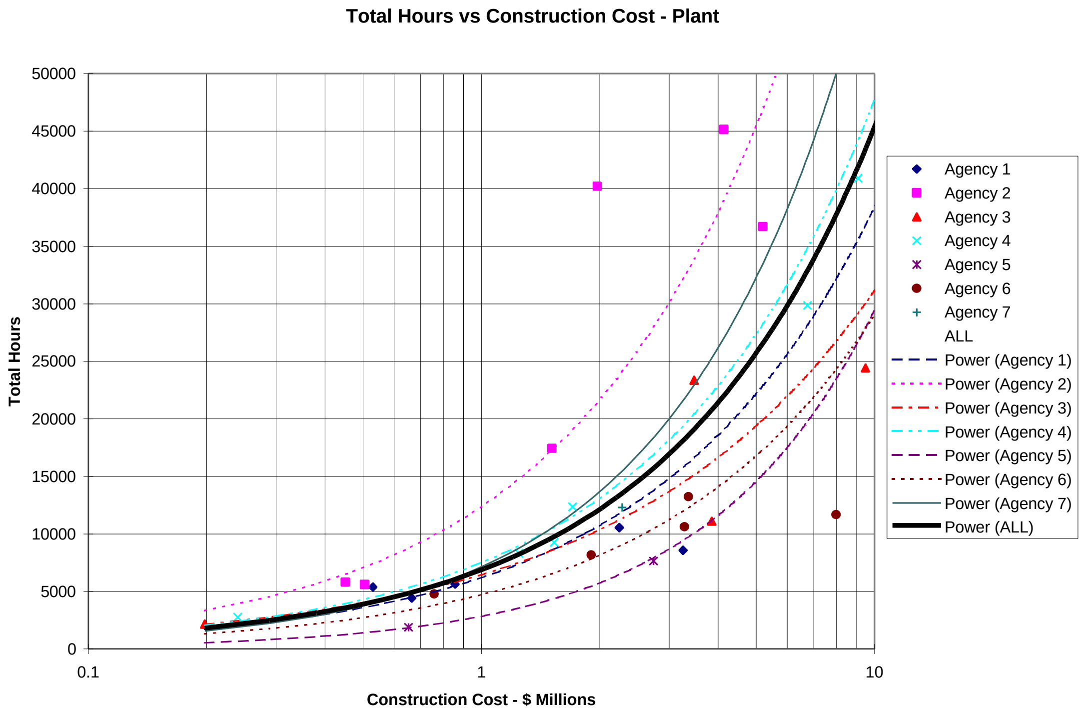
CM Hours vs Construction Cost - Collection System

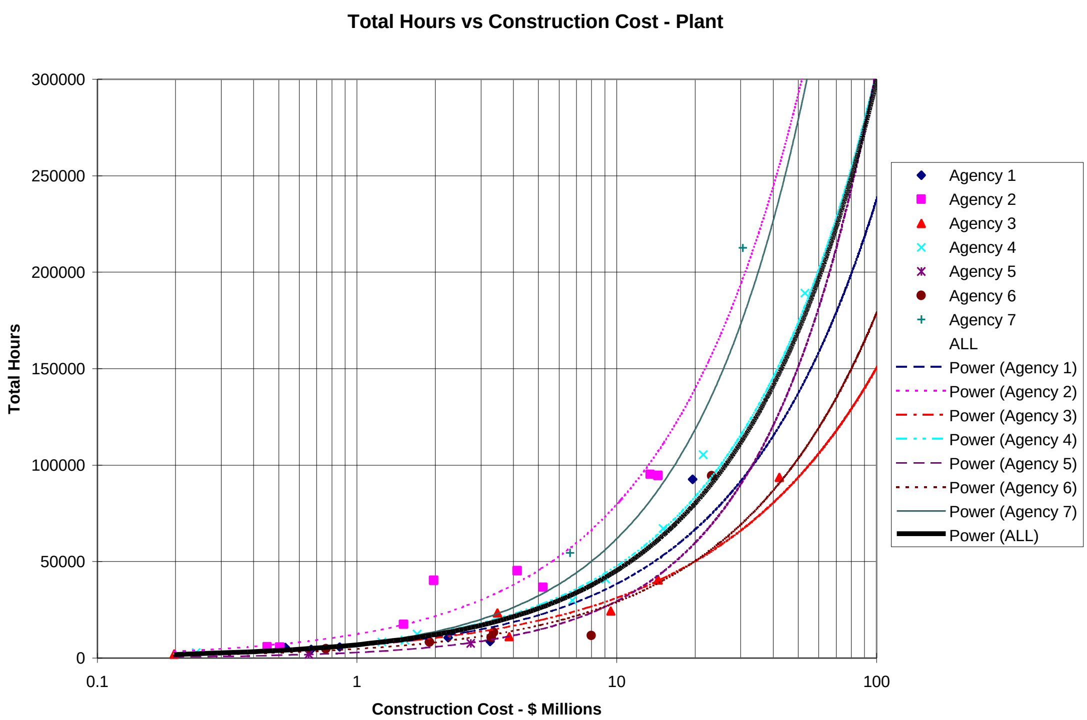


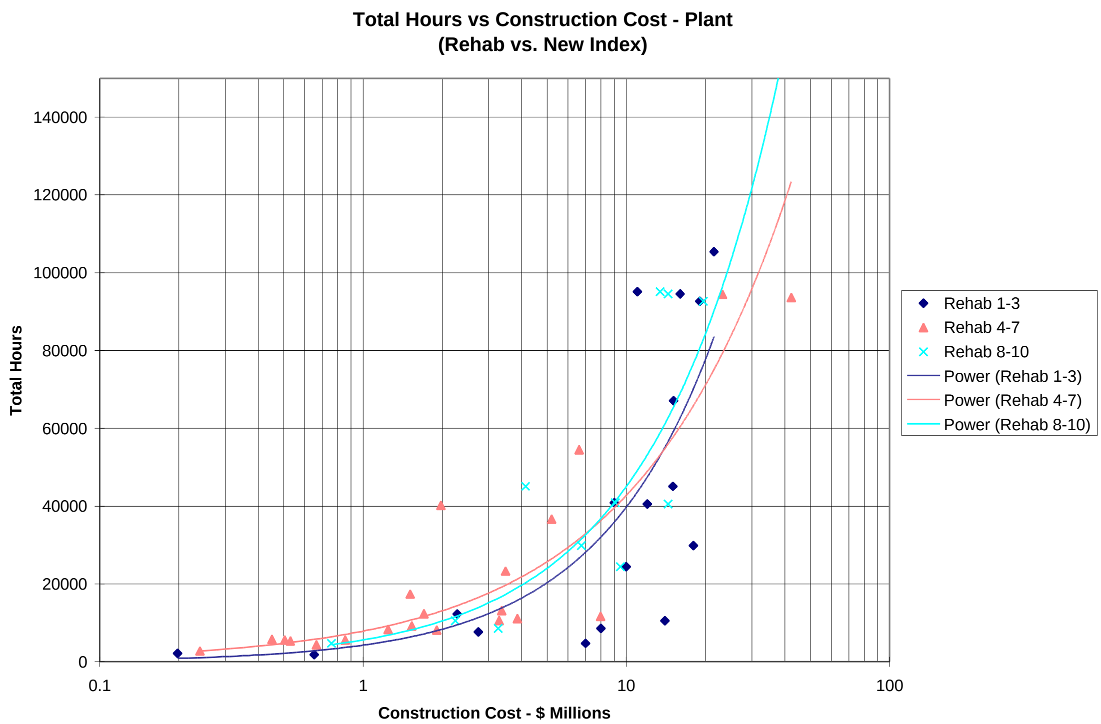

CM Hours vs Construction Cost - Collection System
(Rehab vs. New Index)
80000
70000
60000
50000
40000
30000
20000
10000
0
CM Hours
0.1
1
10
100
Construction Cost - $ Millions
Agency 3
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 4-7)
Power (Rehab 1-3)
Power (Rehab 8-10)

Total Project Hours Versus Construction Cost

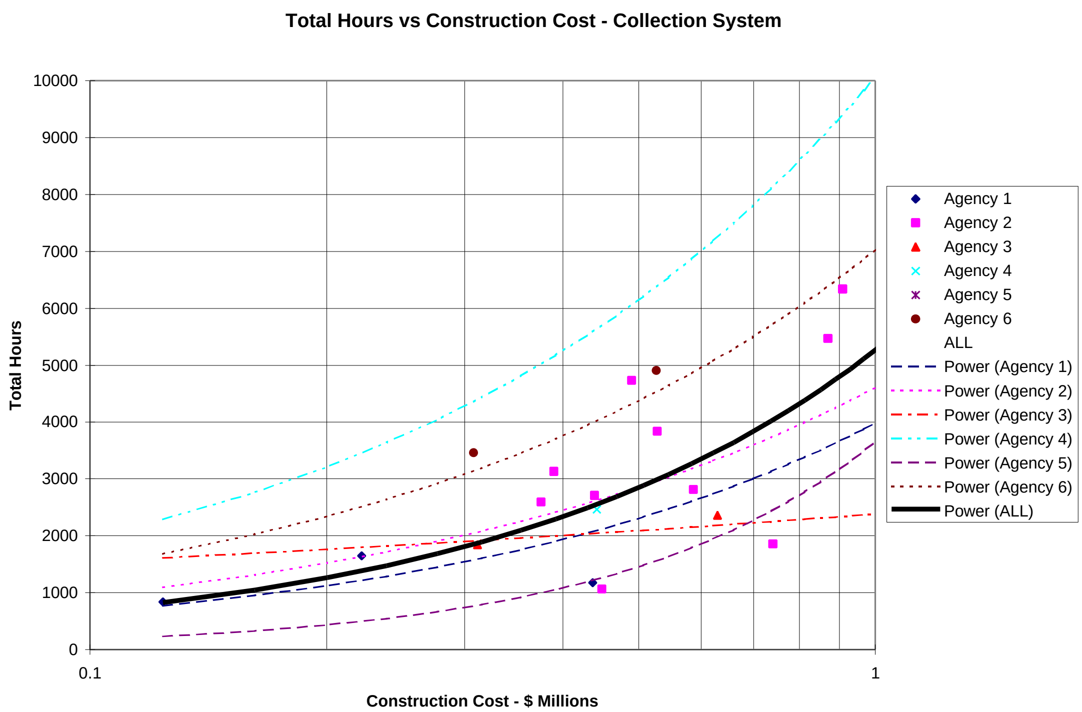
Since these curves are totals of the CM hours and Design hours curves (Chart 1 and 2), the same findings apply.





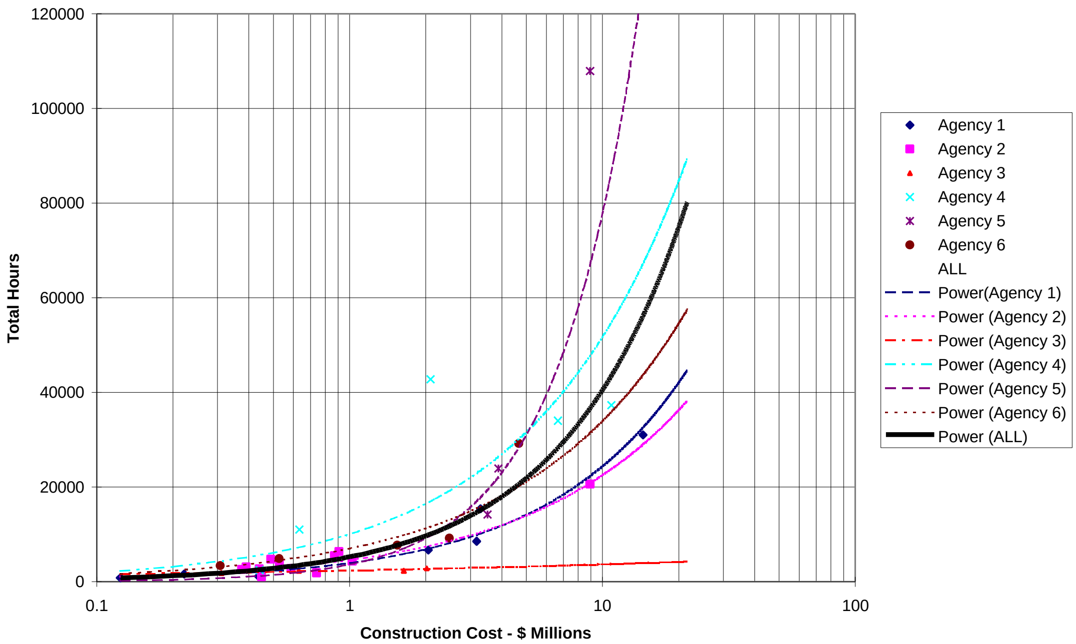


Total Hours vs Construction Cost - Plant
(Rehab vs. New Index)
Total Hours
140000
120000
100000
80000
60000
40000
20000
0
0.1
1
10
100
Construction Cost - $ Millions
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 1-3)
Power (Rehab 4-7)
Power (Rehab 8-10)

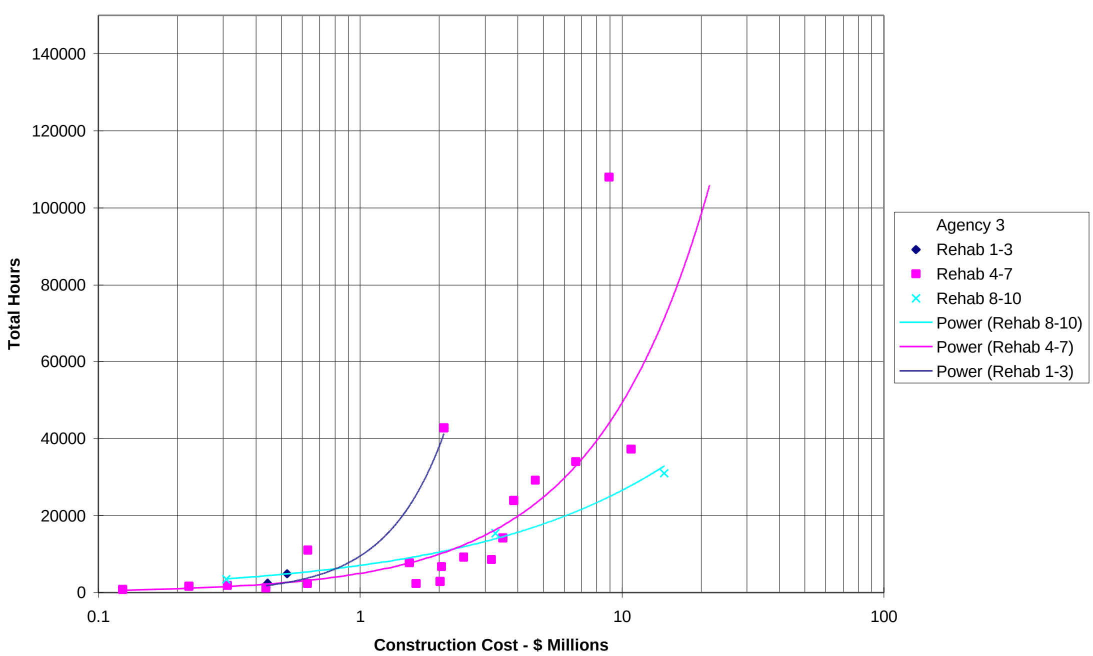


Total Hours vs Construction Cost - Collection System
Total Hours
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.1
1
Construction Cost - $ Millions
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (ALL)

Total Hours vs Construction Cost - Collection System



Total Hours vs Construction Cost - Collection System

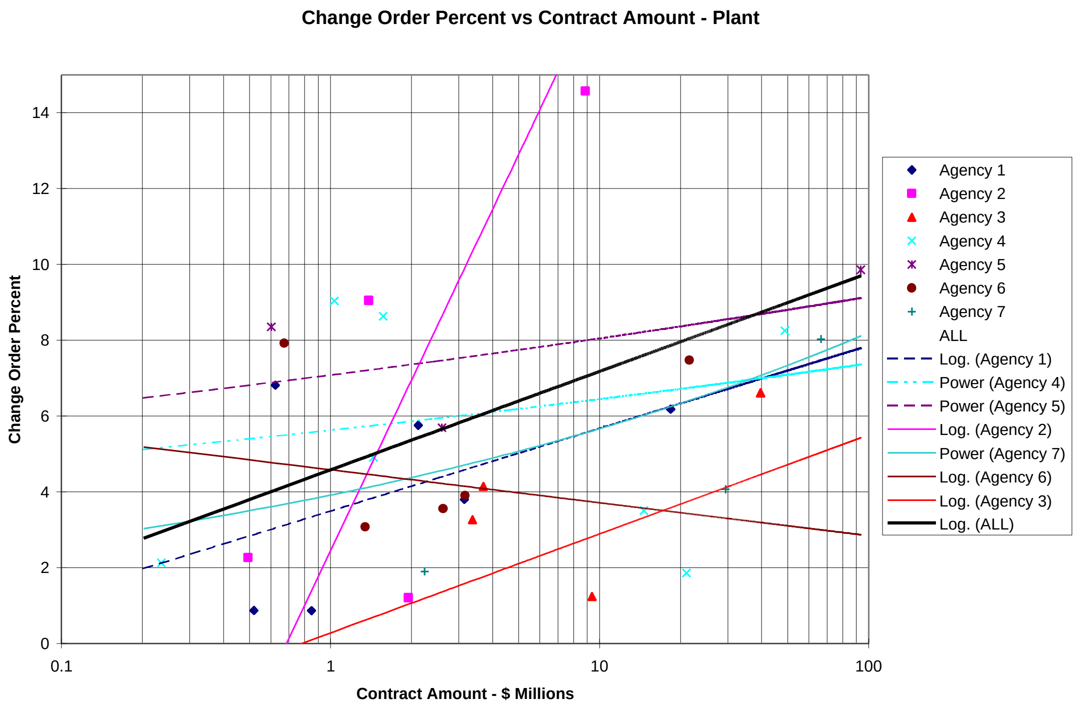


Change Order Percent Versus Construction Costs

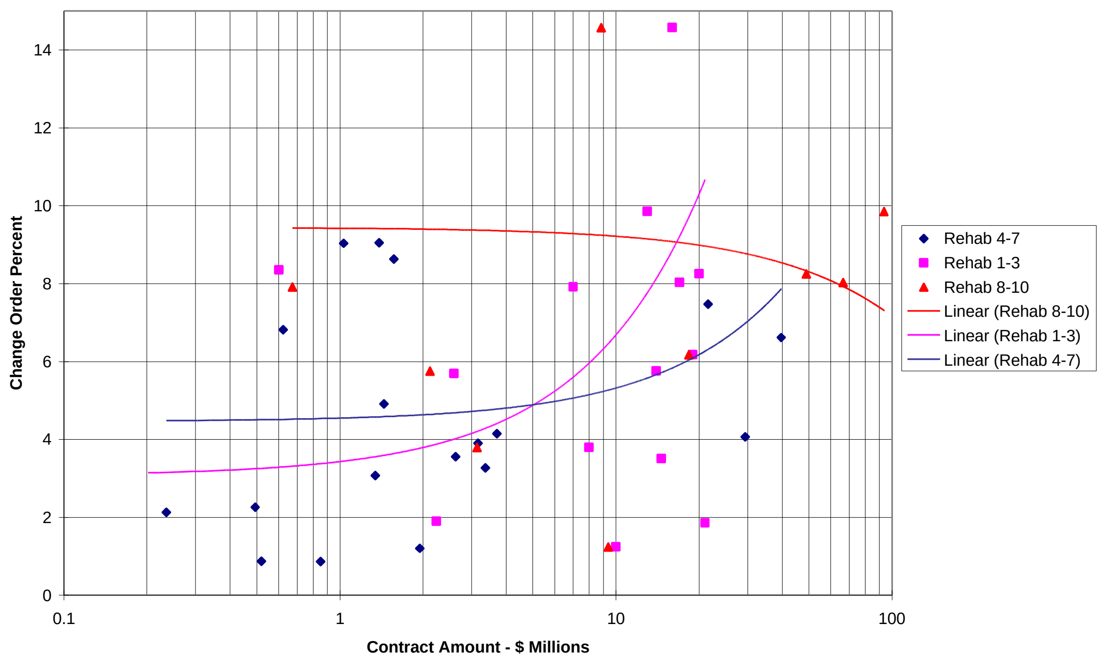
The data scatter is substantial, indicating that the curves are not well fit to the data. Change order percentages vary widely for both collection system and plant projects and within individual agencies, indicating that they may affected more by the specifics of the project rather than by a management approach. The graphs may also be indicating that change order rates by agency may vary based upon each agencies view of how to handle extra work (i.e., by adding it as a change order or holding it over for a new project).

Overall, change order percentages for collection system work are higher than for plant work.

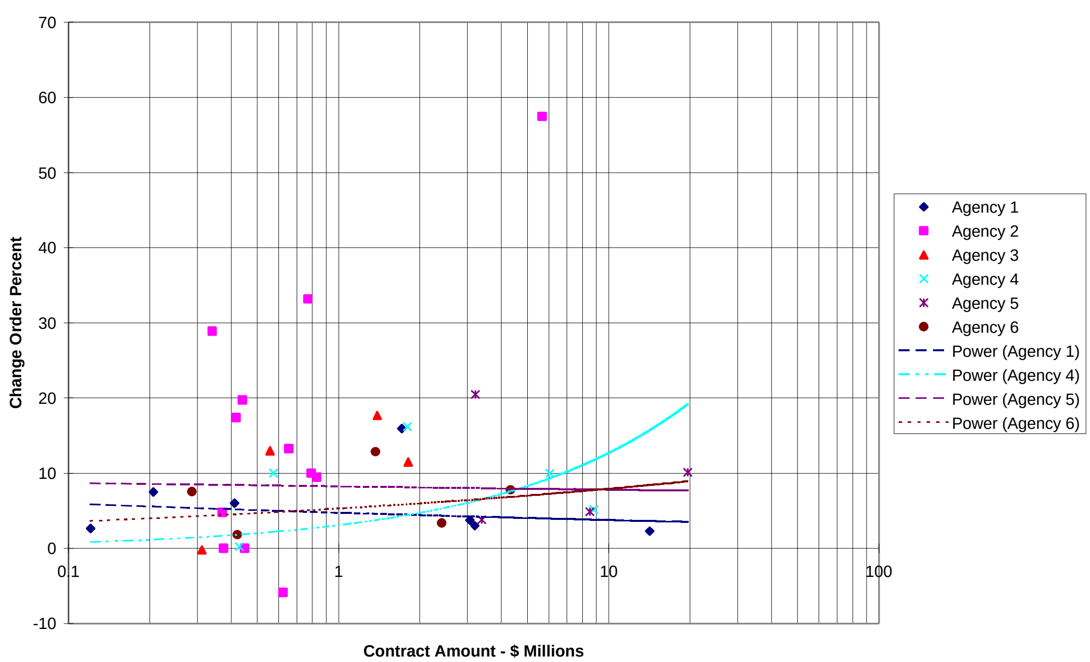
The curves for Rehab versus New do not seem to indicate much. Based on the data point scatter, the curves seem inconclusive.

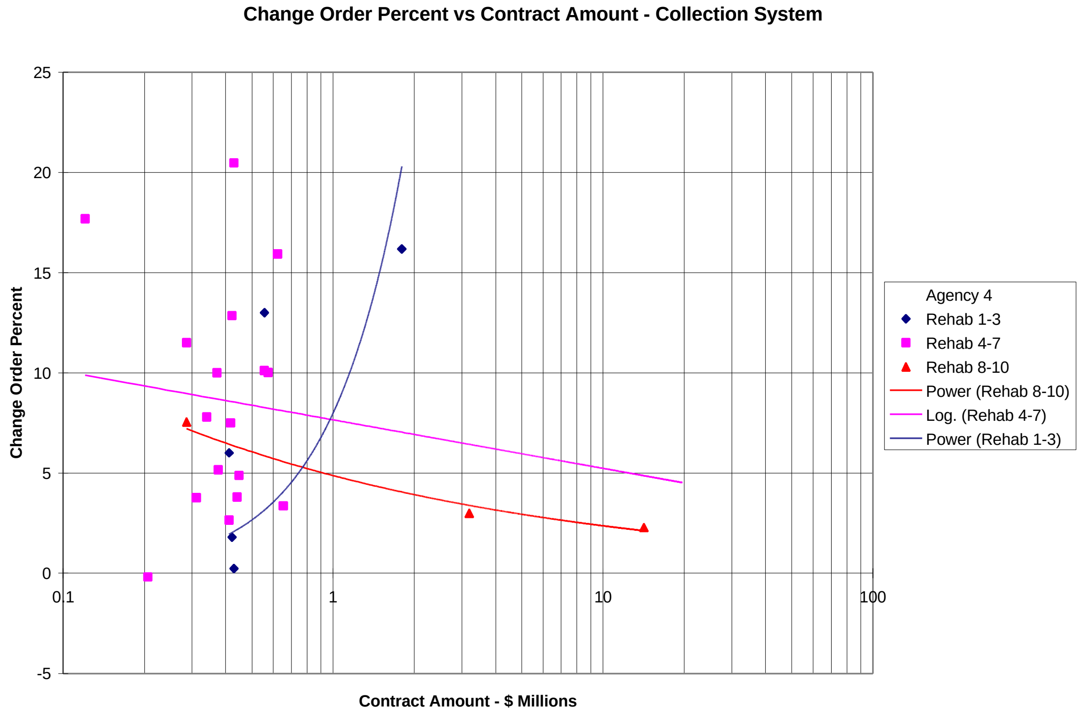


Change Order Percent vs Contract Amount - Plant (Rehab vs. New Index)



Change Order Percent vs Contract Amount - Collection System



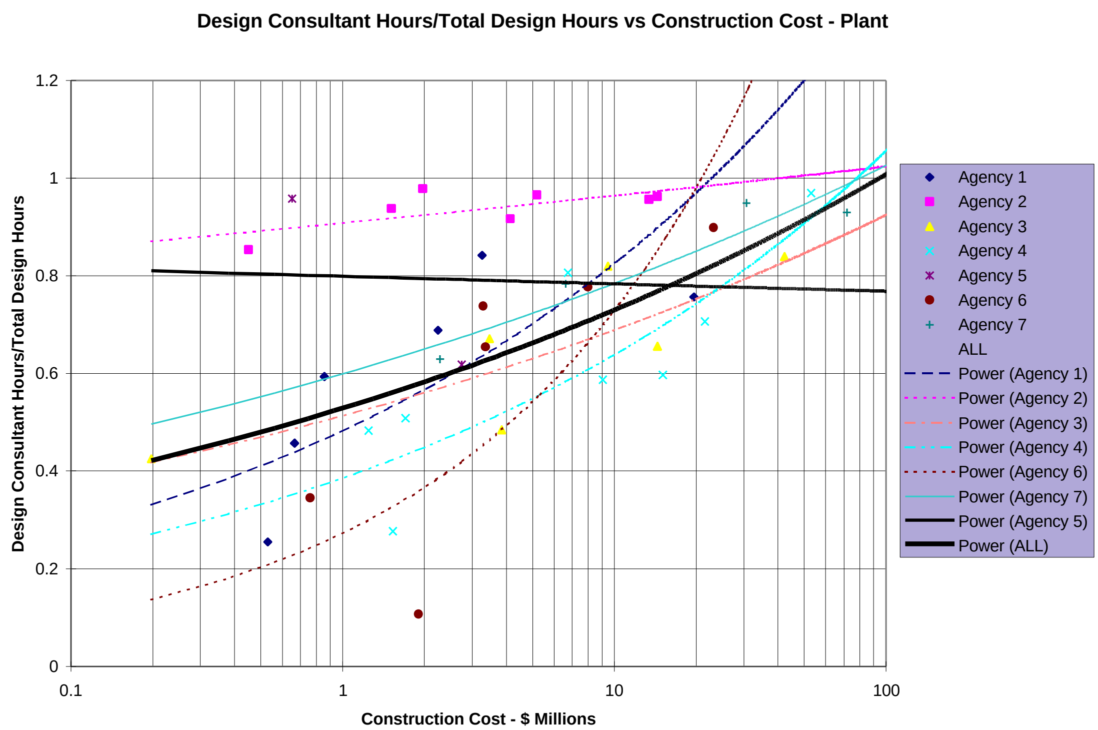

Change Order Percent vs Contract Amount - Collection System
Change Order Percent
Contract Amount - $ Millions
25
20
15
10
5
0
-5
0.1
1
10
100
Agency 4
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 8-10)
Log. (Rehab 4-7)
Power (Rehab 1-3)

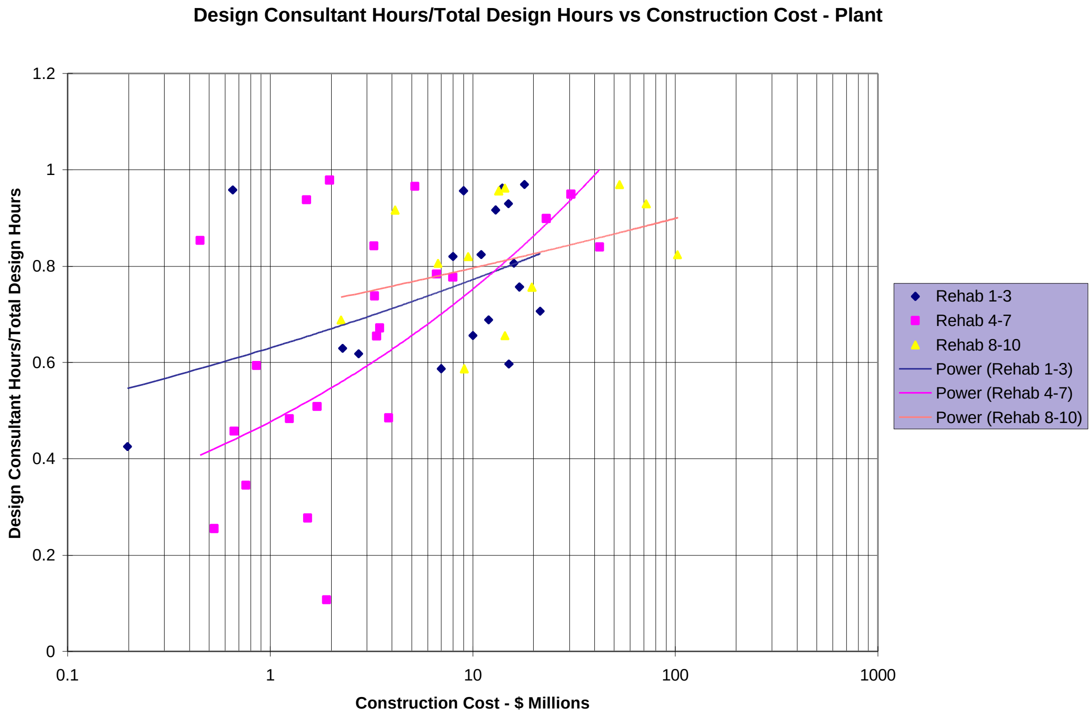
Rates of Consultant to In-house Engineers Versus Construction Costs

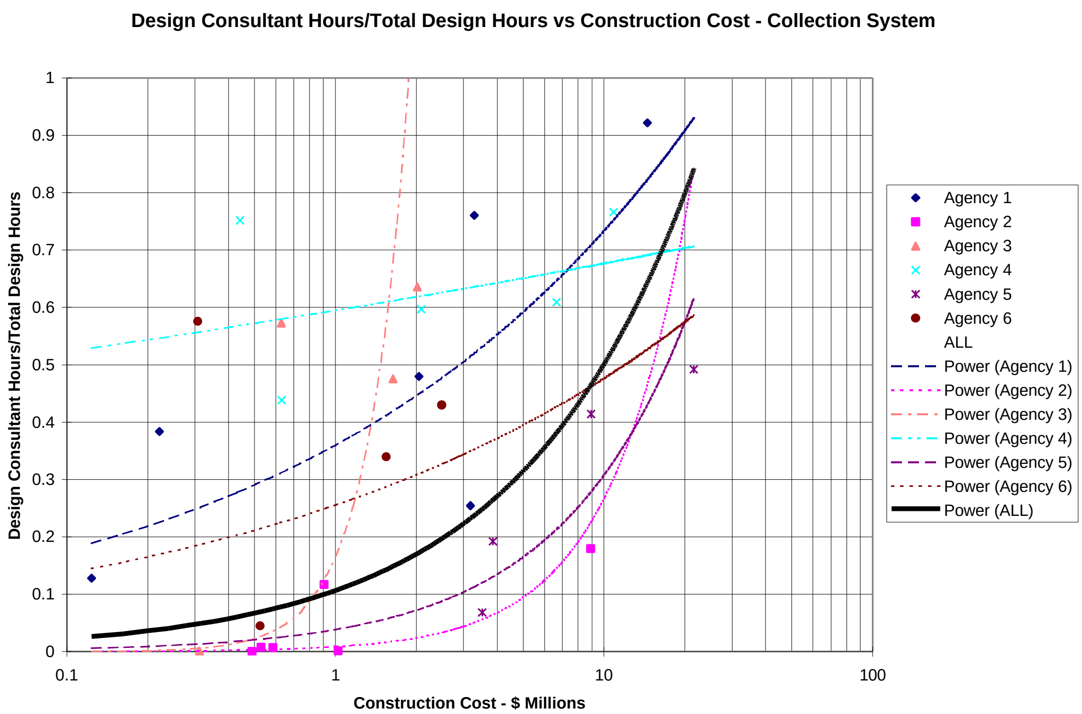
In keeping with agency responses on the Staffing Process Questionnaire, agencies that traditionally have consultants do their design work have higher ratios of consultant hours/total design hours. Several agencies indicated they did small design projects in-house. This is borne out by the data. Lower construction cost projects had lower ratios of consultant hours/total design hours. Generally, as construction costs increased, so did the ratios.

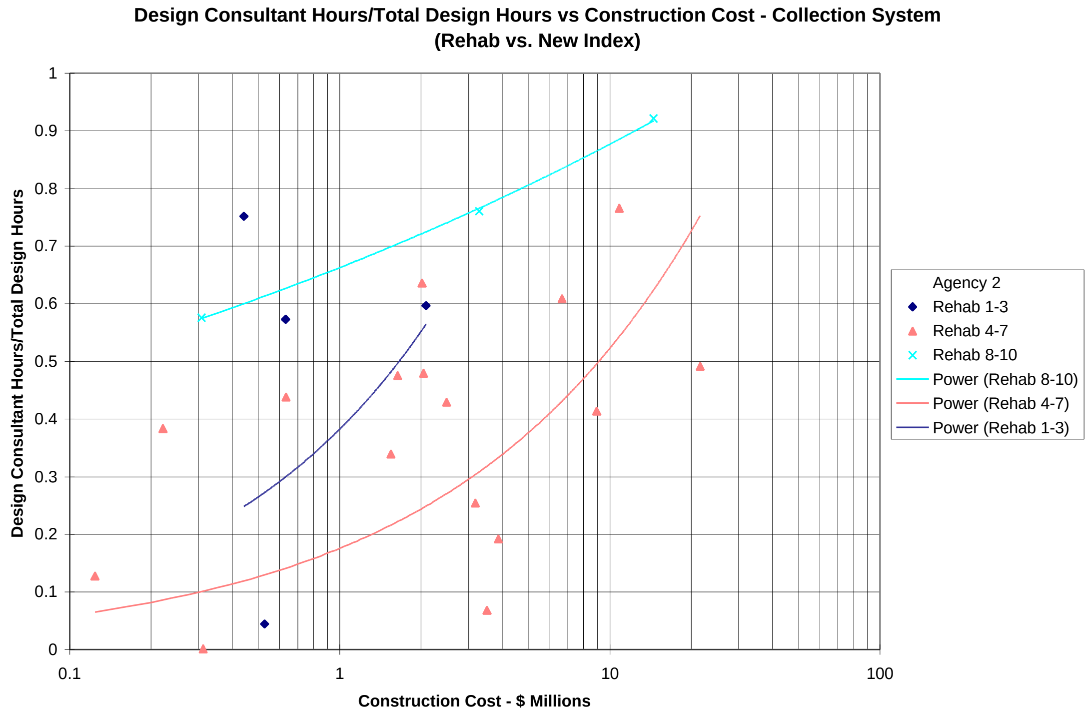
The graphs tend to indicate that, as construction costs increase, agencies use more outside consultant hours compared to in-house staff design hours. This may be done to avoid major staffing fluctuations.

The Rehab versus New curves might indicate that the more complex the projects the more likely outside consultants will be used for the majority of the design work.




Design Consultant Hours/Total Design Hours vs Construction Cost - Plant
Design Consultant Hours/Total Design Hours
Construction Cost - $ Millions
0
0.2
0.4
0.6
0.8
1
1.2
0.1
1
10
100
1000
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 1-3)
Power (Rehab 4-7)
Power (Rehab 8-10)


Design Consultant Hours/Total Design Hours vs Construction Cost - Collection System
Design Consultant Hours/Total Design Hours
Construction Cost - $ Millions
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.1
1
10
100
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (ALL)



Design Consultant Hours/Total Design Hours vs Construction Cost - Collection System
(Rehab vs. New Index)
Design Consultant Hours/Total Design Hours
Construction Cost - $ Millions
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
1
10
100
Agency 2
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 8-10)
Power (Rehab 4-7)
Power (Rehab 1-3)

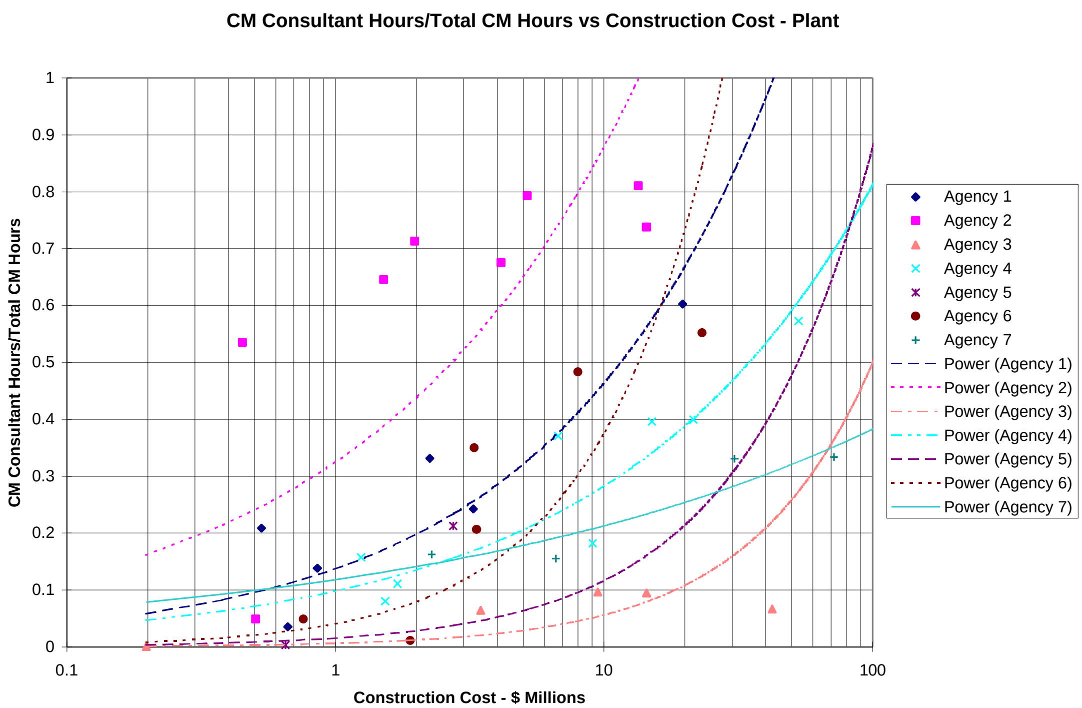
Construction Management Consultant Hours/Total Construction Management Hours Versus Construction Cost

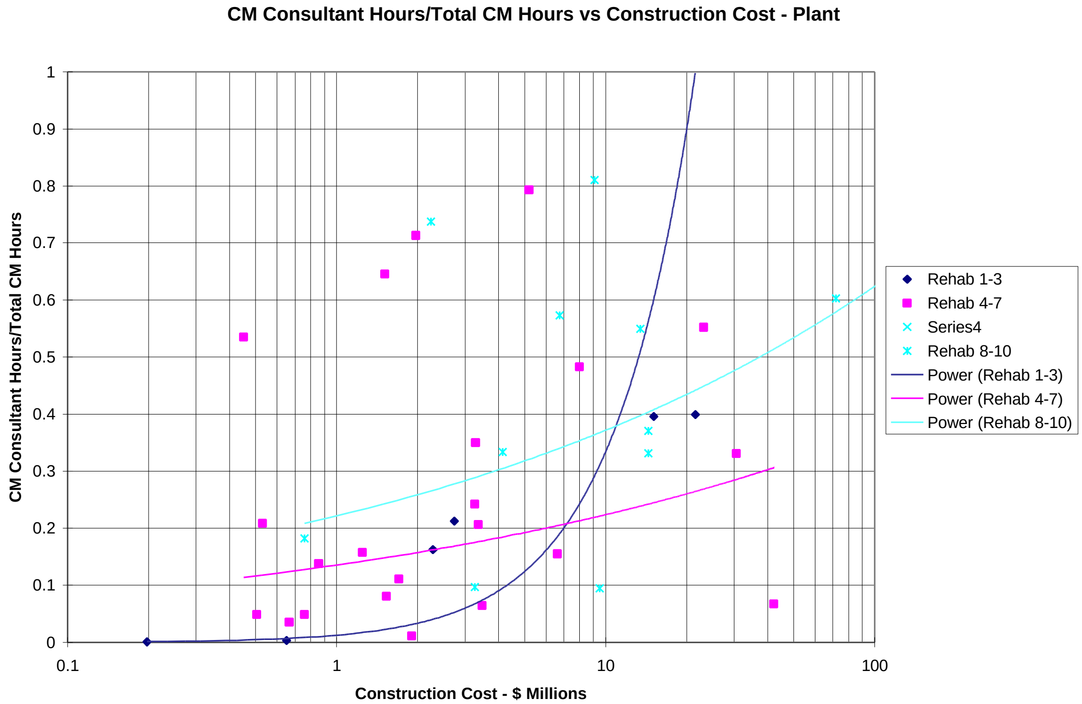
The trend of the data seems to agree with the responses on the Staffing Process Questionnaires. Agencies that use more consultant support for CM show higher ratios.

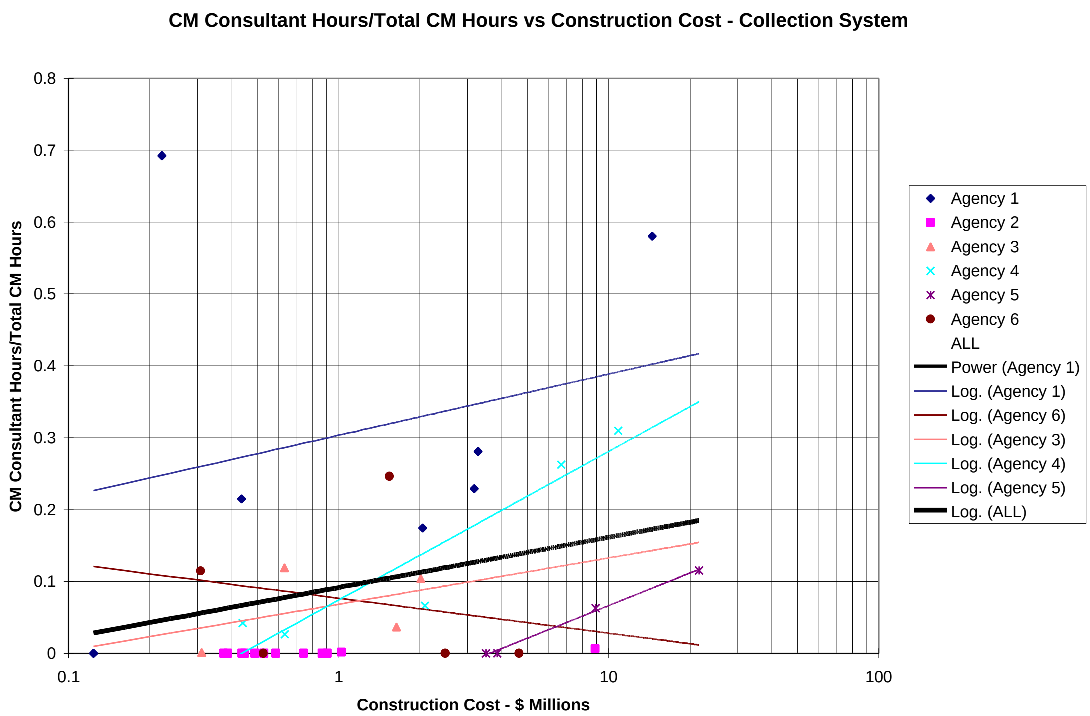
As construction costs increase, so do the ratios for CM consultant support.

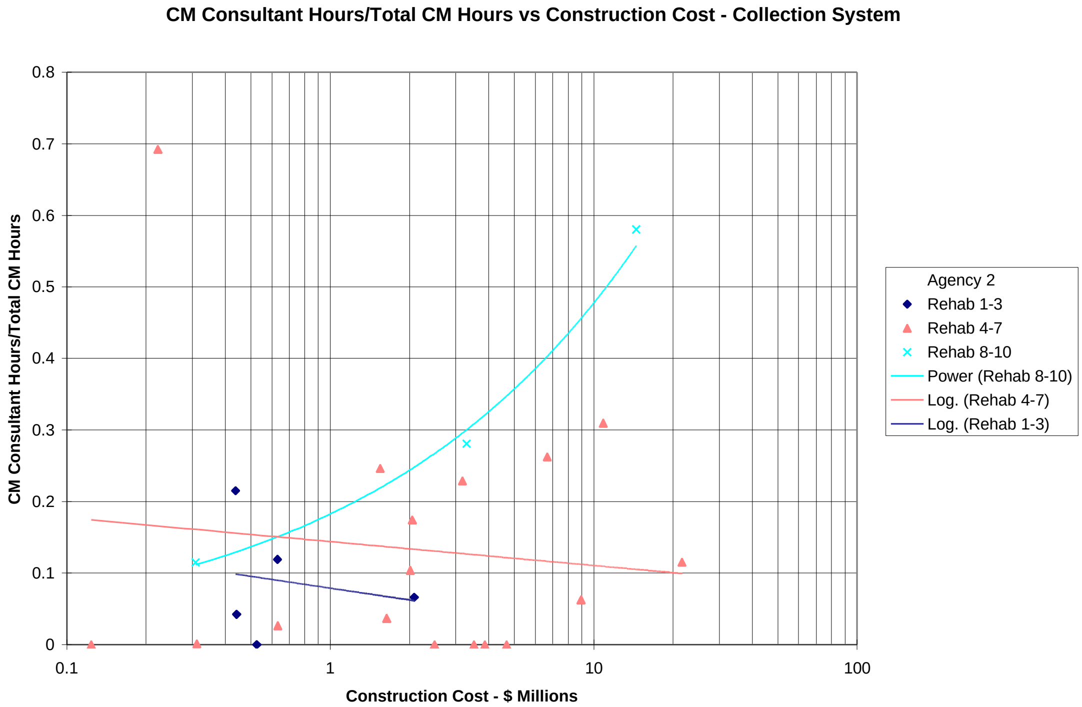
Ratios are lower for collection system projects, indicating most agencies do their own CM.

The Rehab versus New curves would seem to indicate that consultant involvement with CM support goes up with increasing complexity for plant work. For collection system work, consultant involvement increases only for the most complex work; otherwise it doesn't vary based on complexity or construction cost.




CM Consultant Hours/Total CM Hours vs Construction Cost - Plant
CM Consultant Hours/Total CM Hours
Construction Cost - $ Millions
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.1
1
10
100
Rehab 1-3
Rehab 4-7
Series4
Rehab 8-10
Power (Rehab 1-3)
Power (Rehab 4-7)
Power (Rehab 8-10)


CM Consultant Hours/Total CM Hours vs Construction Cost - Collection System
CM Consultant Hours/Total CM Hours
Construction Cost - $ Millions
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.1
1
10
100
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Log. (Agency 1)
Log. (Agency 6)
Log. (Agency 3)
Log. (Agency 4)
Log. (Agency 5)
Log. (ALL)

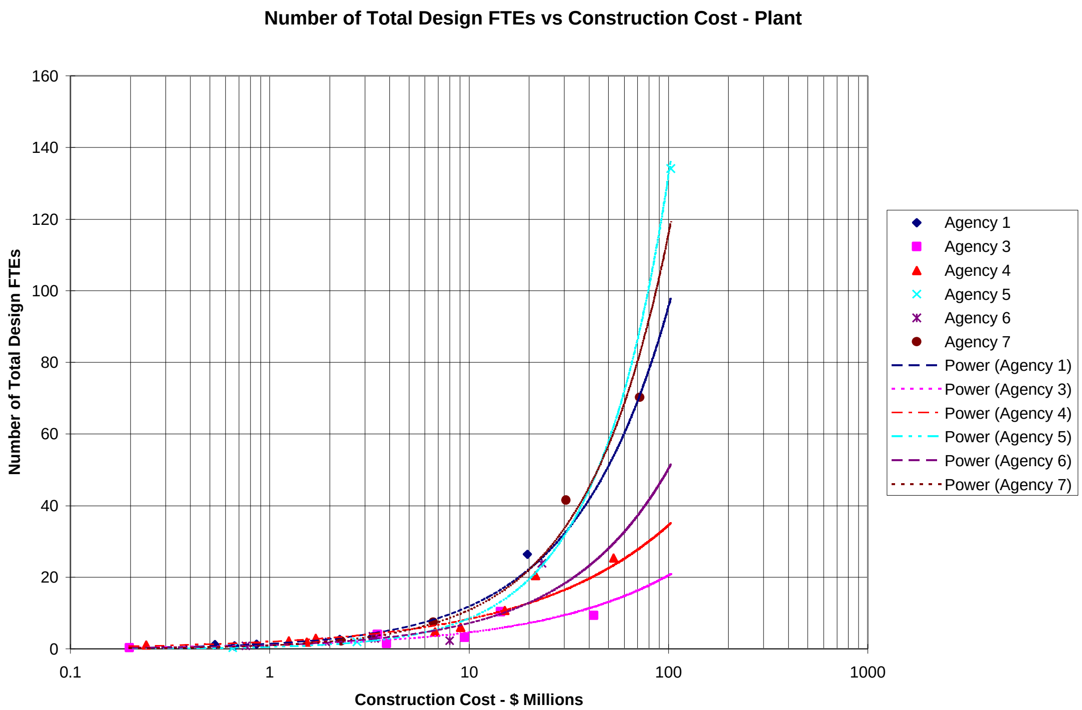

CM Consultant Hours/Total CM Hours vs Construction Cost - Collection System
CM Consultant Hours/Total CM Hours
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 2
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 8-10)
Log. (Rehab 4-7)
Log. (Rehab 1-3)

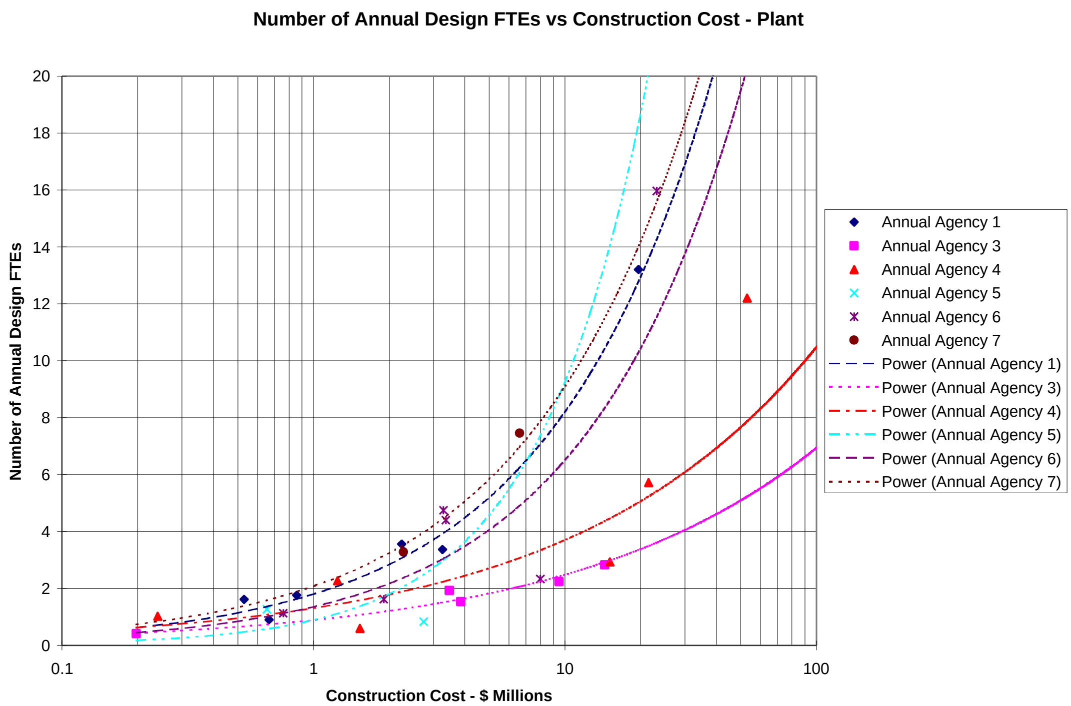
Number of FTEs Versus Construction Costs

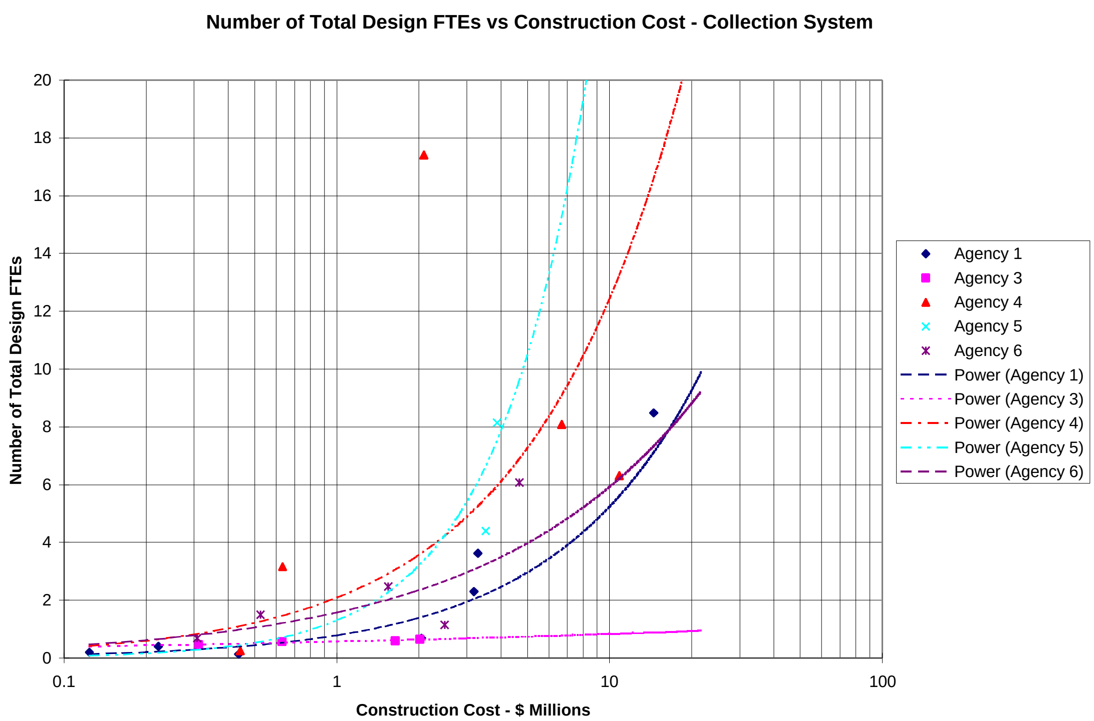
Number of Total Design FTEs Versus Construction Cost and Number of Annual Design FTEs Versus Construction Cost

The curves indicate that all the agencies have less than two annual or total design FTEs for construction projects under $1 million, whether collection system or plant.

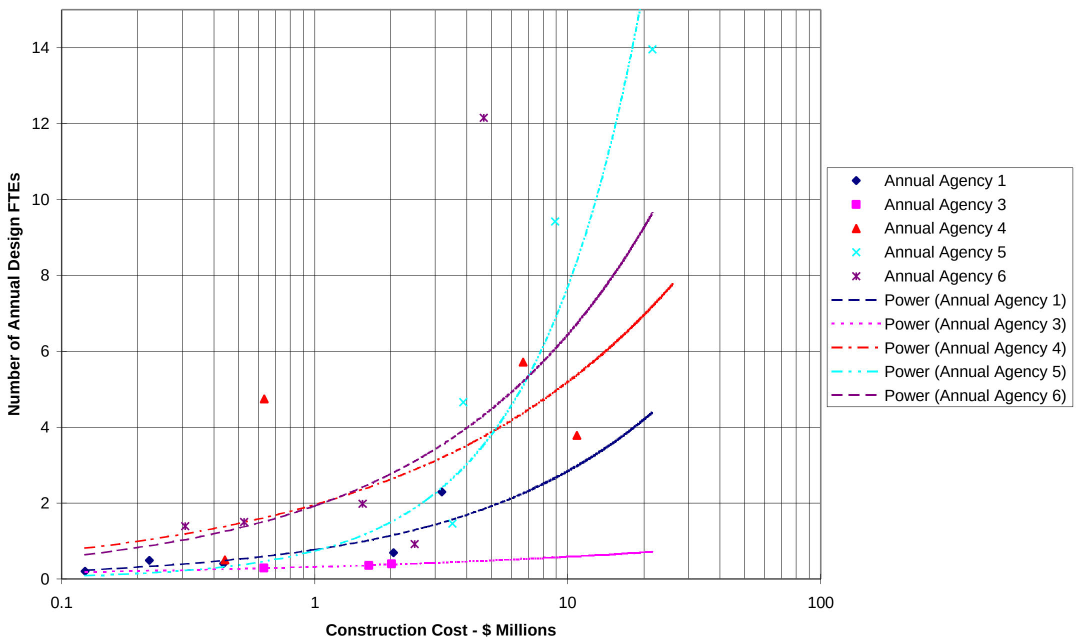
Above $1 million in construction cost, there is substantial divergence between the agencies.




Number of Annual Design FTEs vs Construction Cost - Plant
Number of Annual Design FTEs
Construction Cost - $ Millions
0
2
4
6
8
10
12
14
16
18
20
0.1
1
10
100
Annual Agency 1
Annual Agency 3
Annual Agency 4
Annual Agency 5
Annual Agency 6
Annual Agency 7
Power (Annual Agency 1)
Power (Annual Agency 3)
Power (Annual Agency 4)
Power (Annual Agency 5)
Power (Annual Agency 6)
Power (Annual Agency 7)


Number of Total Design FTEs vs Construction Cost - Collection System
Number of Total Design FTEs
Construction Cost - $ Millions
0
2
4
6
8
10
12
14
16
18
20
0.1
1
10
100
Agency 1
Agency 3
Agency 4
Agency 5
Agency 6
Power (Agency 1)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)

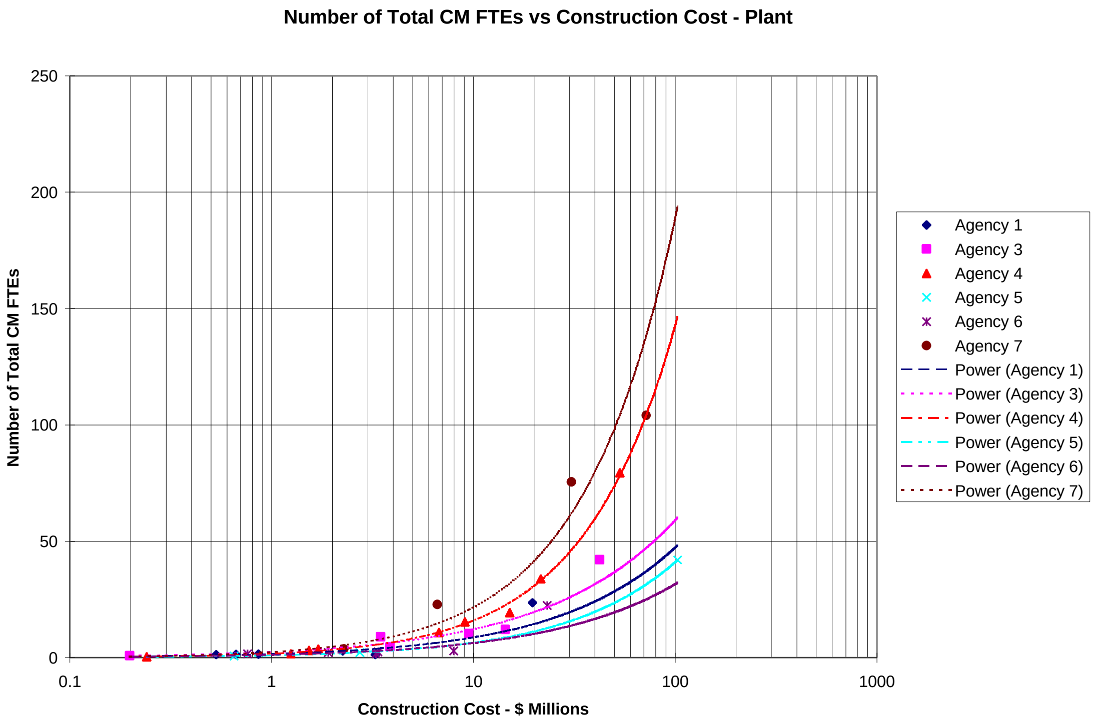
Number of Annual Design FTEs vs Construction Cost - Collection System



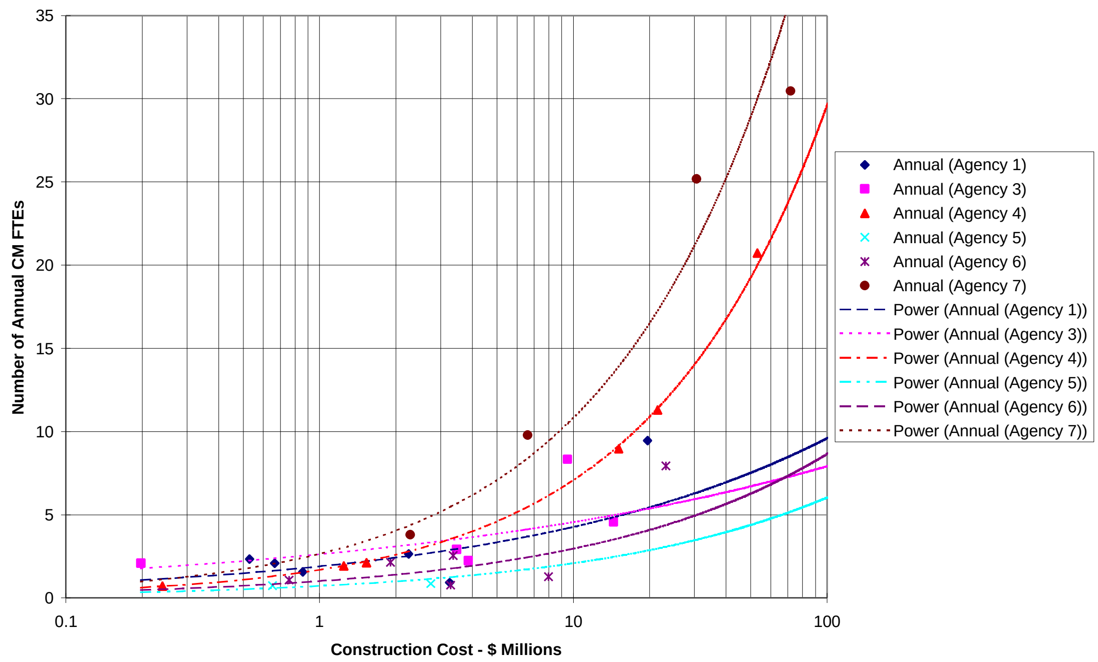
Number of Total CM FTEs Versus Construction Cost and Number of Annual CM FTEs Versus Construction Cost

The curves indicate that all the agencies have less than two to three annual or total CM FTEs for construction projects under $1 million, whether collection system or plant.

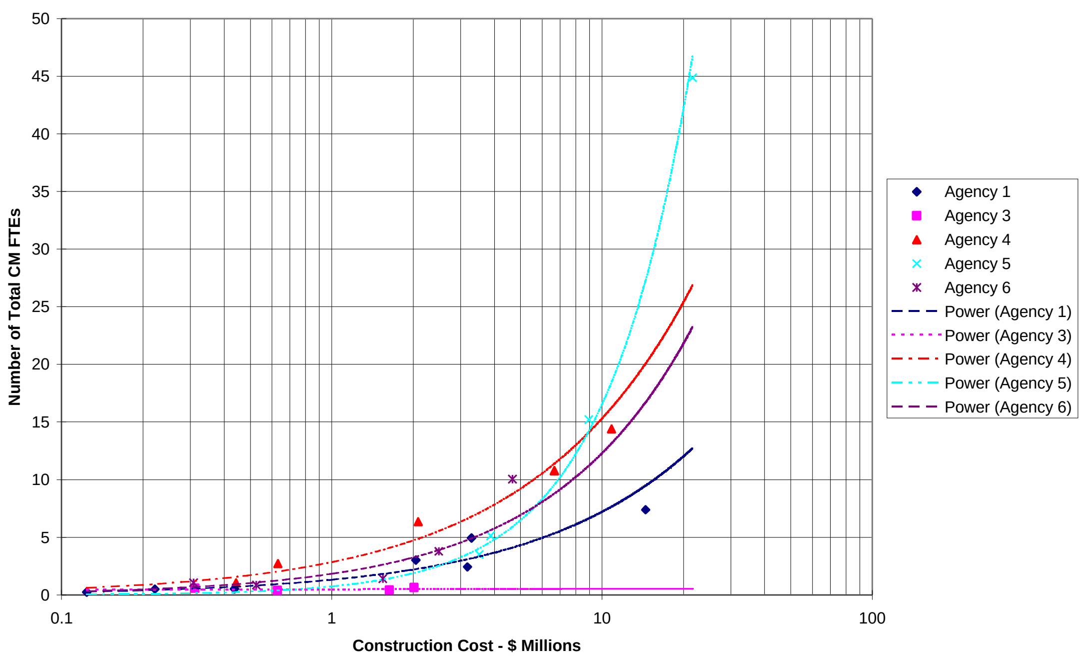
Above $1 million in construction cost, there is substantial divergence between the agencies.

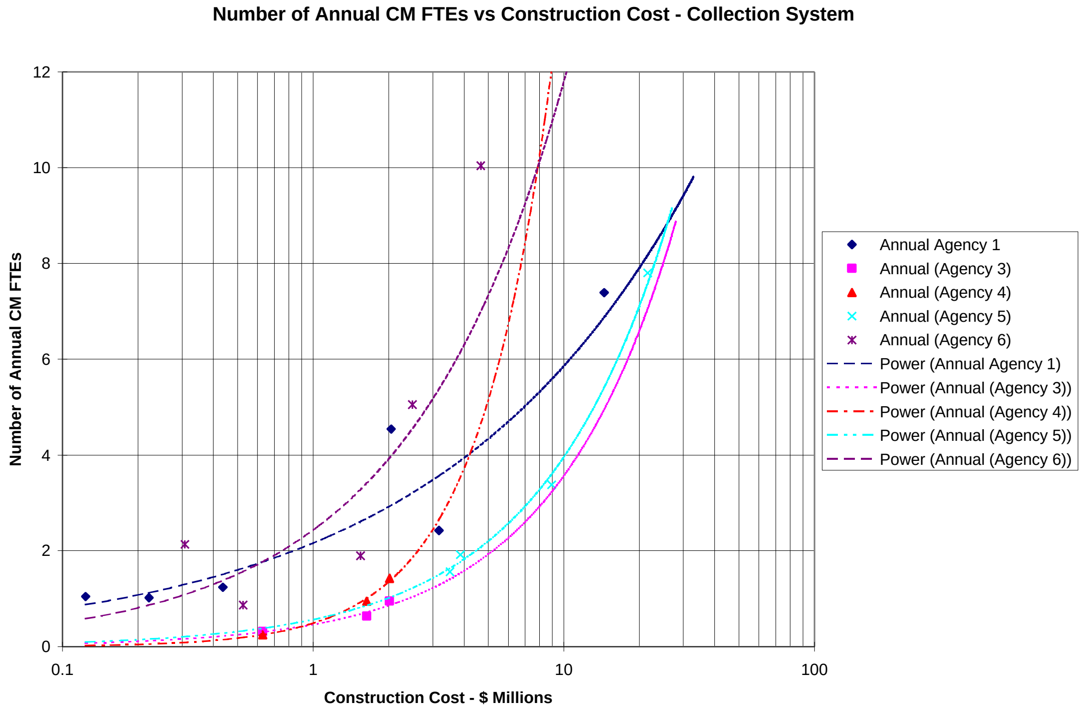


Number of Annual CM FTEs vs Construction Cost - Plant



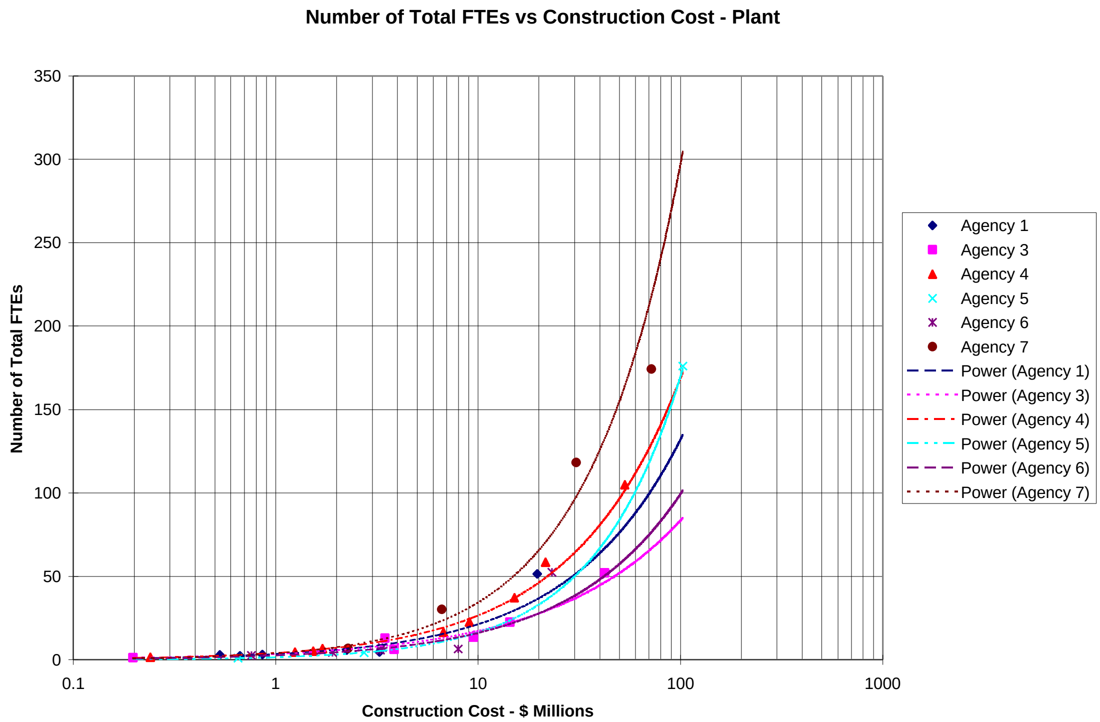
Number of Total CM FTEs vs Construction Cost - Collection System

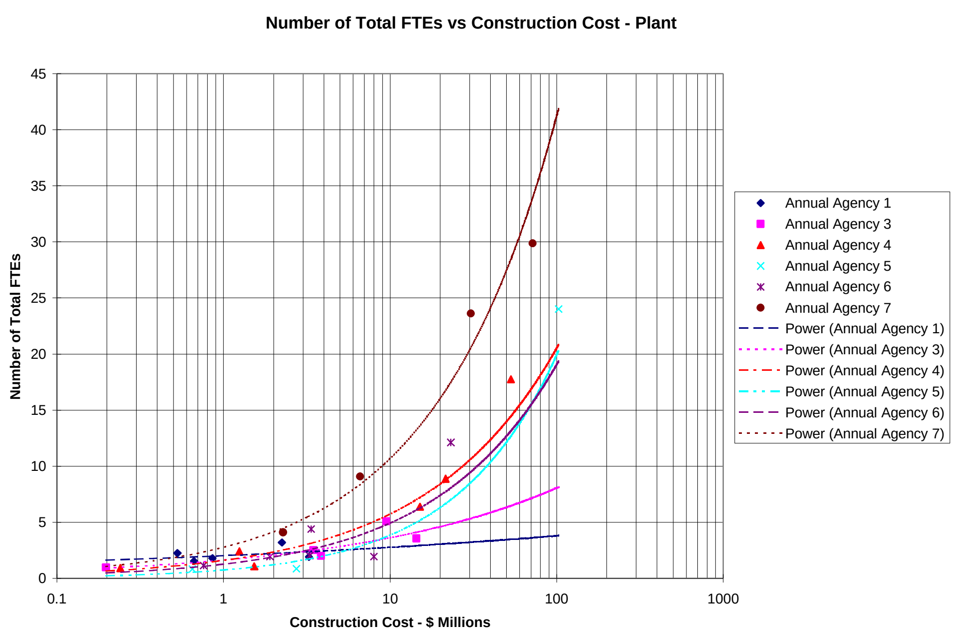


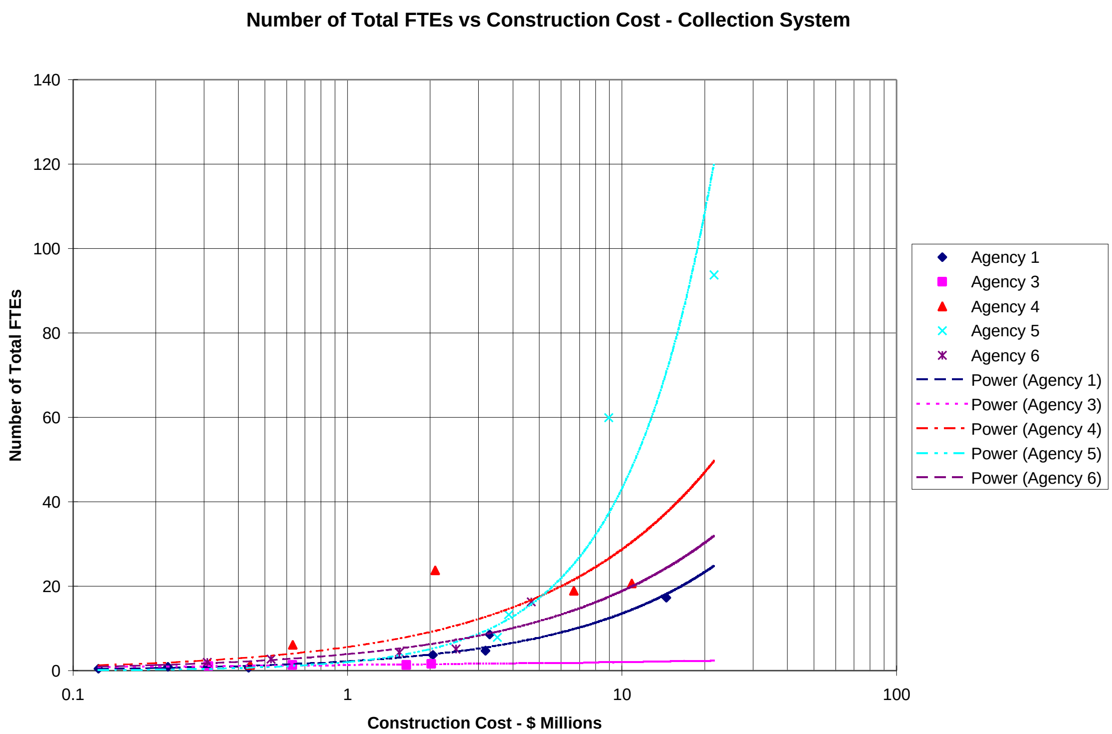

Number of Annual CM FTEs vs Construction Cost - Collection System
Number of Annual CM FTEs
Construction Cost - $ Millions
0
2
4
6
8
10
12
0.1
1
10
100
Annual Agency 1
Annual (Agency 3)
Annual (Agency 4)
Annual (Agency 5)
Annual (Agency 6)
Power (Annual Agency 1)
Power (Annual (Agency 3))
Power (Annual (Agency 4))
Power (Annual (Agency 5))
Power (Annual (Agency 6))

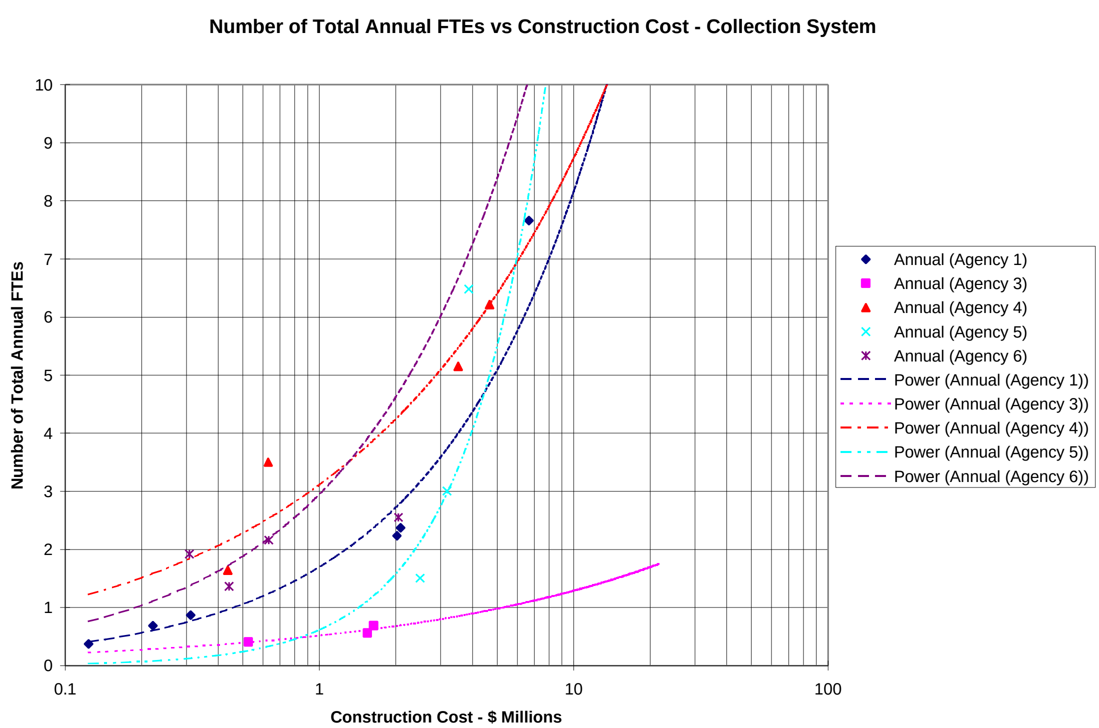
Number of Total FTEs Versus Construction Cost and Number of Annual Total FTEs Versus Construction Cost

Since this is a compilation of the other two charts, the conclusions drawn above apply.



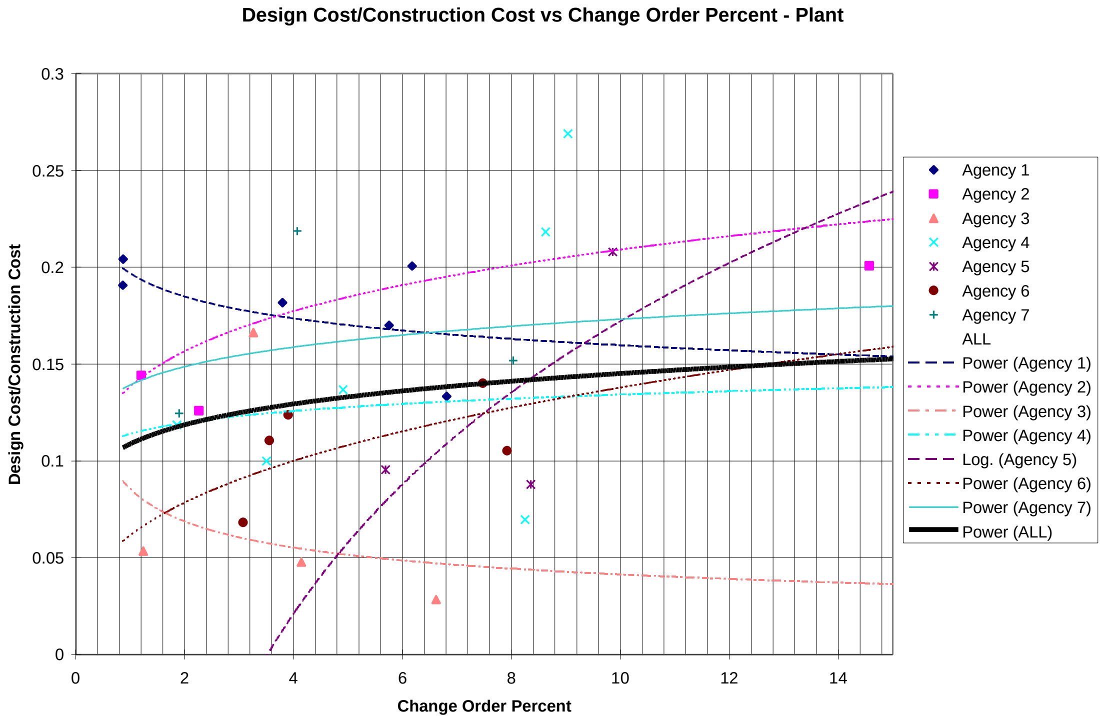


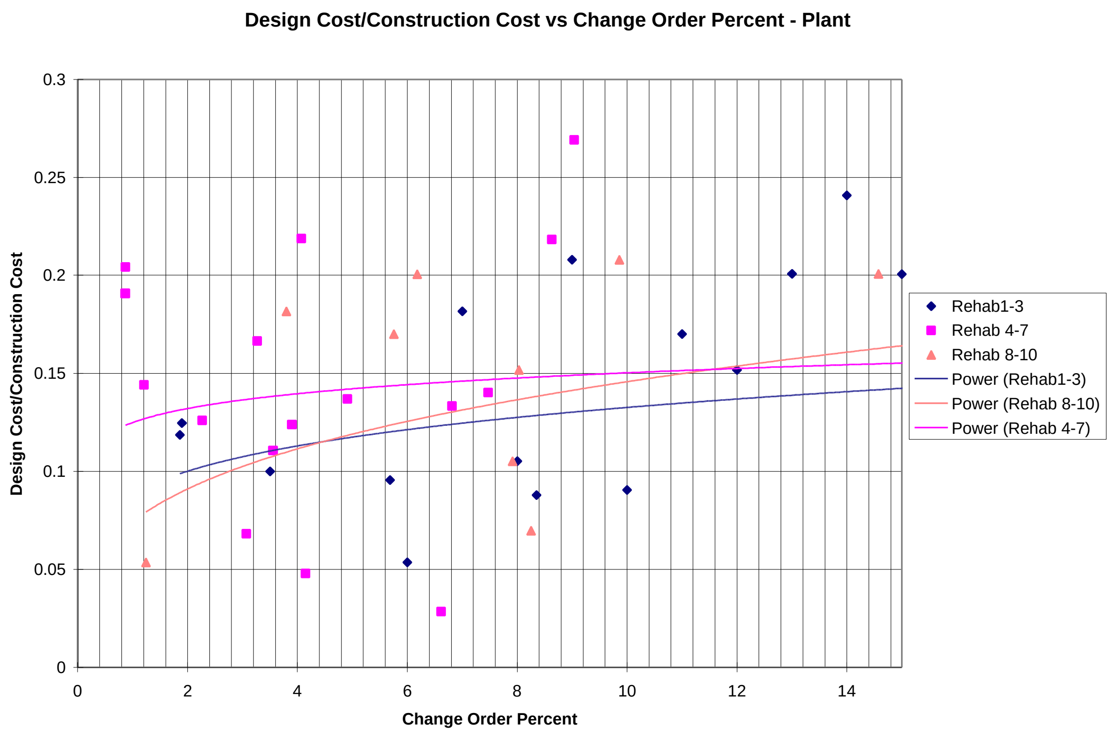

Number of Total FTEs vs Construction Cost - Collection System
140
120
100
80
60
40
20
0
Number of Total FTEs
0.1
1
10
100
Construction Cost - $ Millions
Agency 1
Agency 3
Agency 4
Agency 5
Agency 6
Power (Agency 1)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)

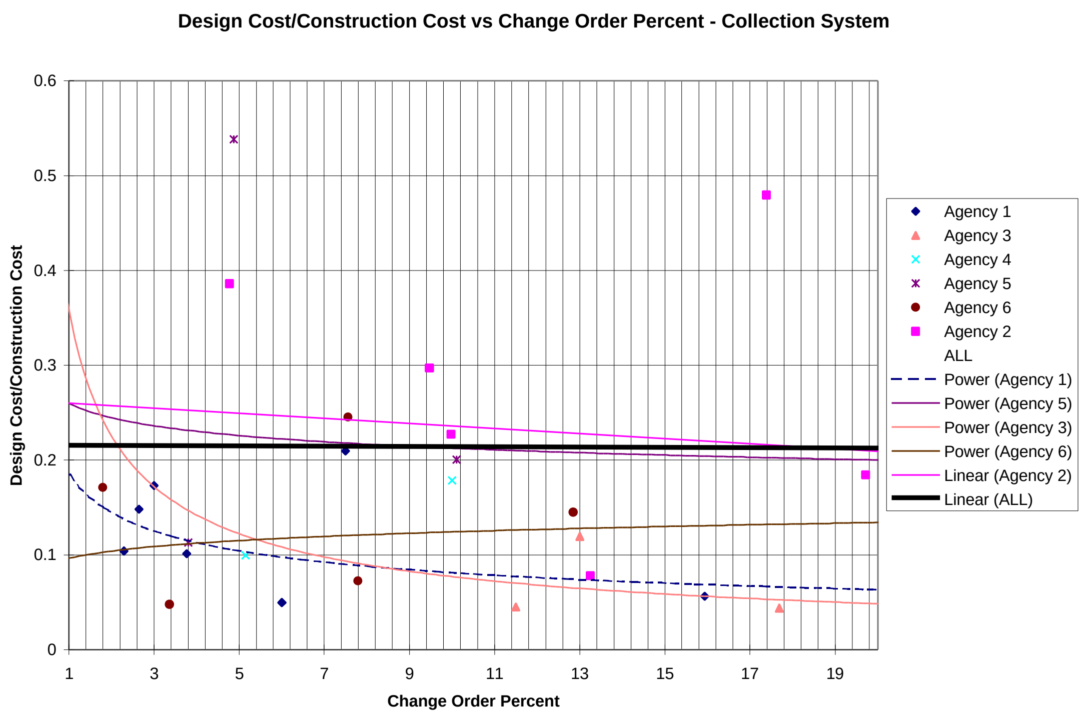

Number of Total Annual FTEs vs Construction Cost - Collection System
10
9
8
7
6
5
4
3
2
1
0
Number of Total Annual FTEs
0.1
1
10
100
Construction Cost - $ Millions
Annual (Agency 1)
Annual (Agency 3)
Annual (Agency 4)
Annual (Agency 5)
Annual (Agency 6)
Power (Annual (Agency 1))
Power (Annual (Agency 3))
Power (Annual (Agency 4))
Power (Annual (Agency 5))
Power (Annual (Agency 6))

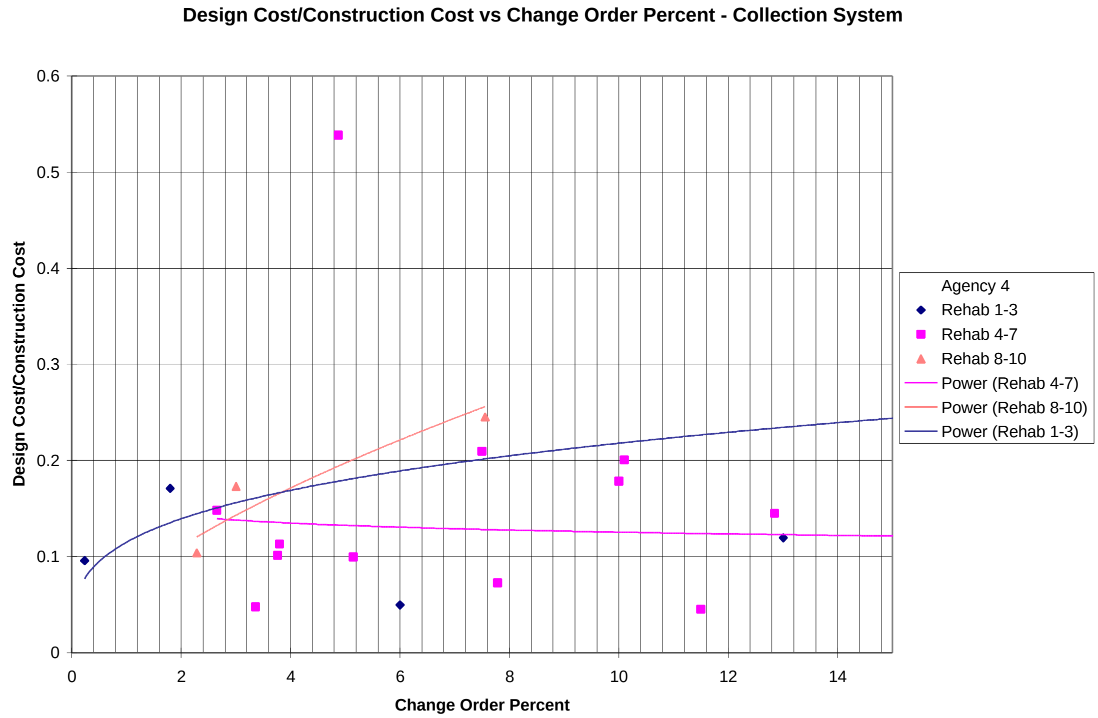
Design Cost/Construction Cost Versus Change Order Percent

The curves are relatively flat, indicating that spending more on design will not reduce the percentage of change orders. No effort was made to categorize the changes related only to design issues, so no correlation can be drawn between the design effort expended and the value of design related changes. The Rehab versus New curves tend to indicate the same conclusion.



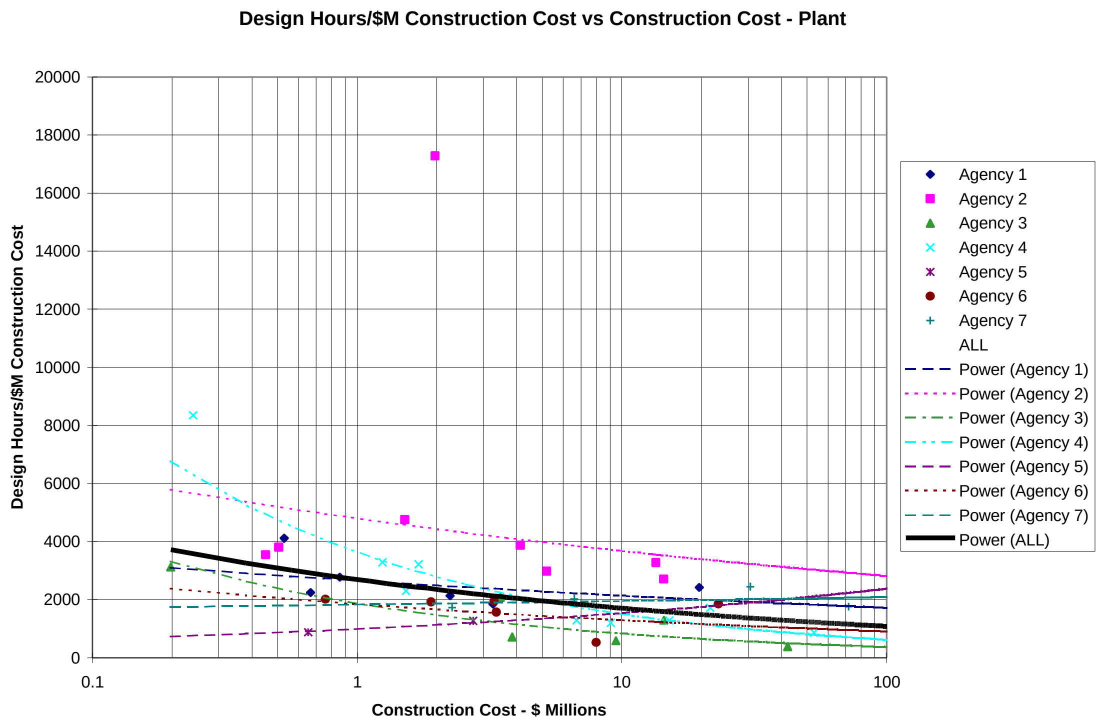

Design Cost/Construction Cost vs Change Order Percent - Plant
Design Cost/Construction Cost
Change Order Percent
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
Rehab1-3
Rehab 4-7
Rehab 8-10
Power (Rehab1-3)
Power (Rehab 8-10)
Power (Rehab 4-7)


Design Cost/Construction Cost vs Change Order Percent - Collection System
Design Cost/Construction Cost
Change Order Percent
0.6
0.5
0.4
0.3
0.2
0.1
0
1
3
5
7
9
11
13
15
17
19
Agency 1
Agency 3
Agency 4
Agency 5
Agency 6
Agency 2
ALL
Power (Agency 1)
Power (Agency 5)
Power (Agency 3)
Power (Agency 6)
Linear (Agency 2)
Linear (ALL)

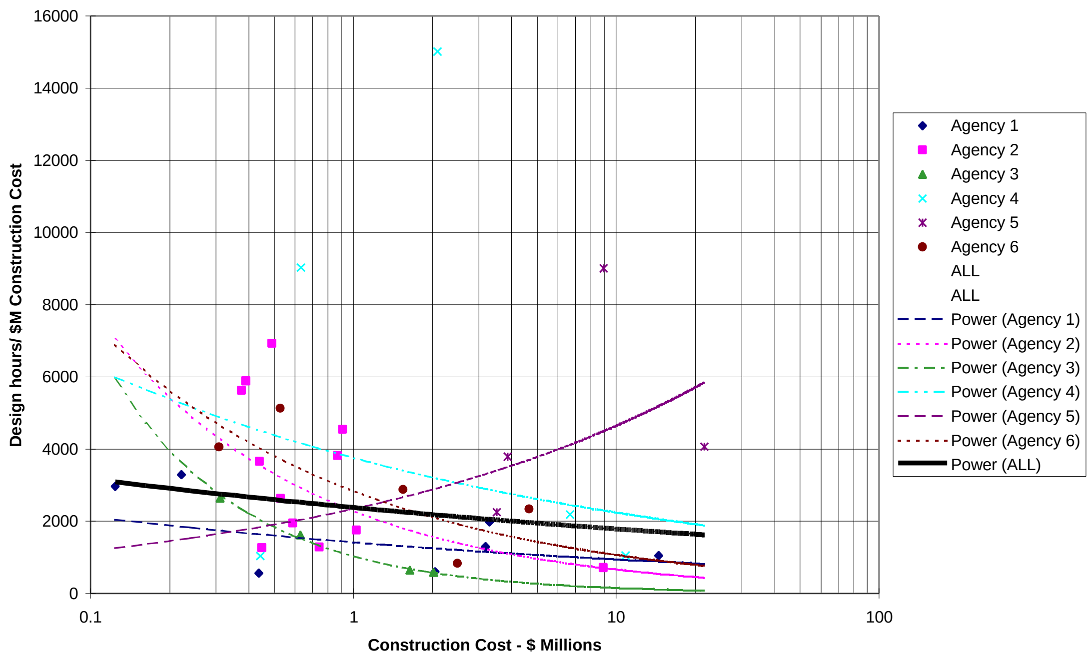

Design Cost/Construction Cost vs Change Order Percent - Collection System
Design Cost/Construction Cost
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
Change Order Percent
Agency 4
Rehab 1-3
Rehab 4-7
Rehab 8-10
Power (Rehab 4-7)
Power (Rehab 8-10)
Power (Rehab 1-3)

Design Hours/$ Million in Construction Cost Versus Construction Cost

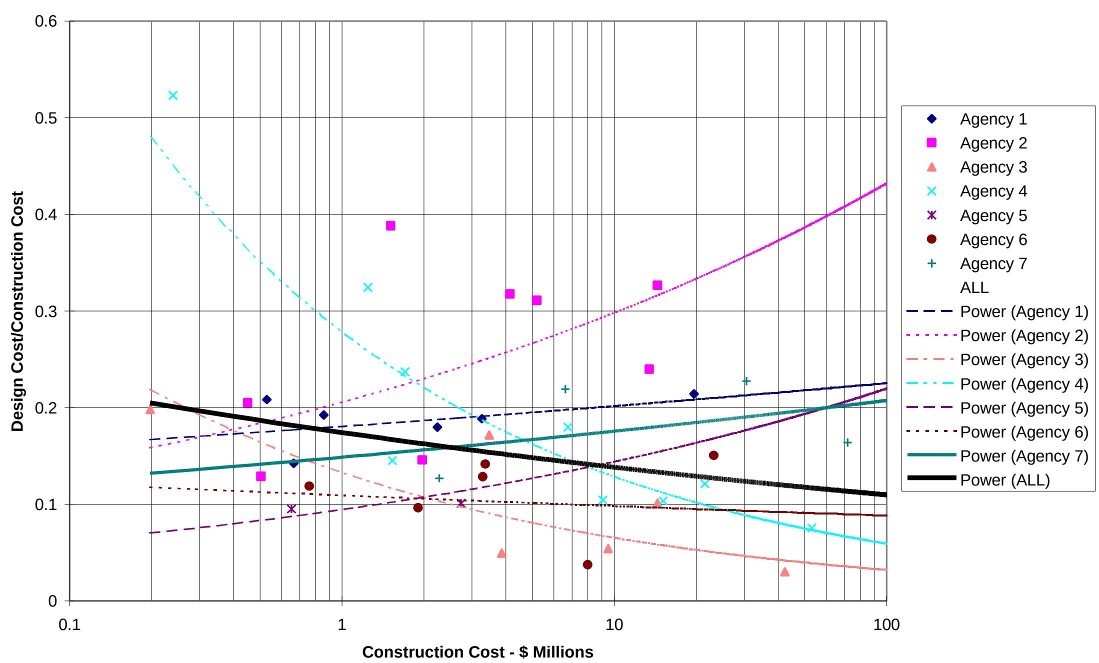
Average design hours/$ million in construction cost in the plants remain relatively constant versus construction cost, in the range of 1,000 to 3,000 hours/$ million construction. Most agencies are relatively near to the average curve for plants. The collections average curve is more constant than plants at 2,000 to 3,000 hours/$ million in construction. However, there is a wider spread of agencies around the average for collection system design. There is a slight downward trend in both average curves, indicating that the level of design effort per dollar spent declines with increased construction costs.



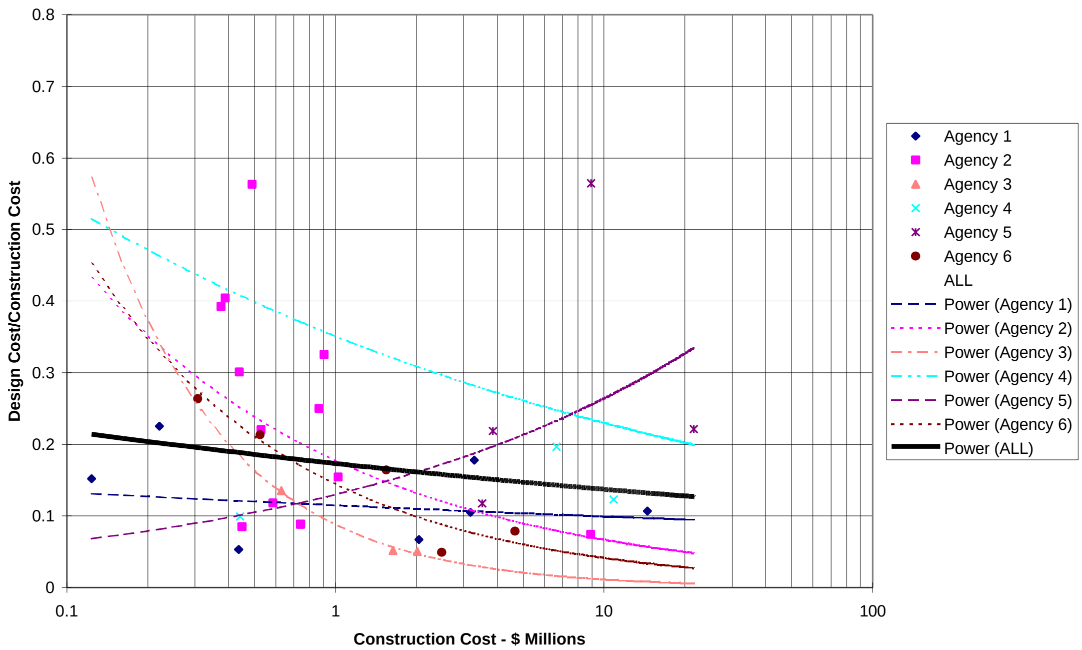
Design Hours/$M Construction Cost vs Construction Cost - Collection System



Design Cost/Construction Cost vs Construction Cost - Plant



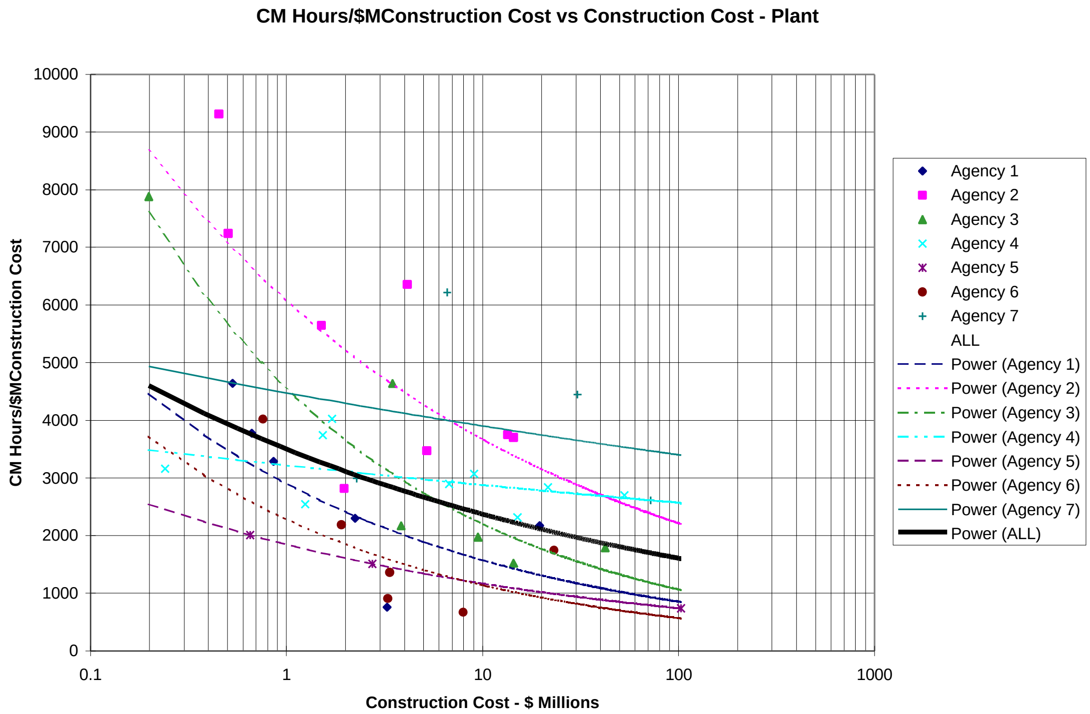
Design Cost/Construction Cost vs Construction Cost - Collection System

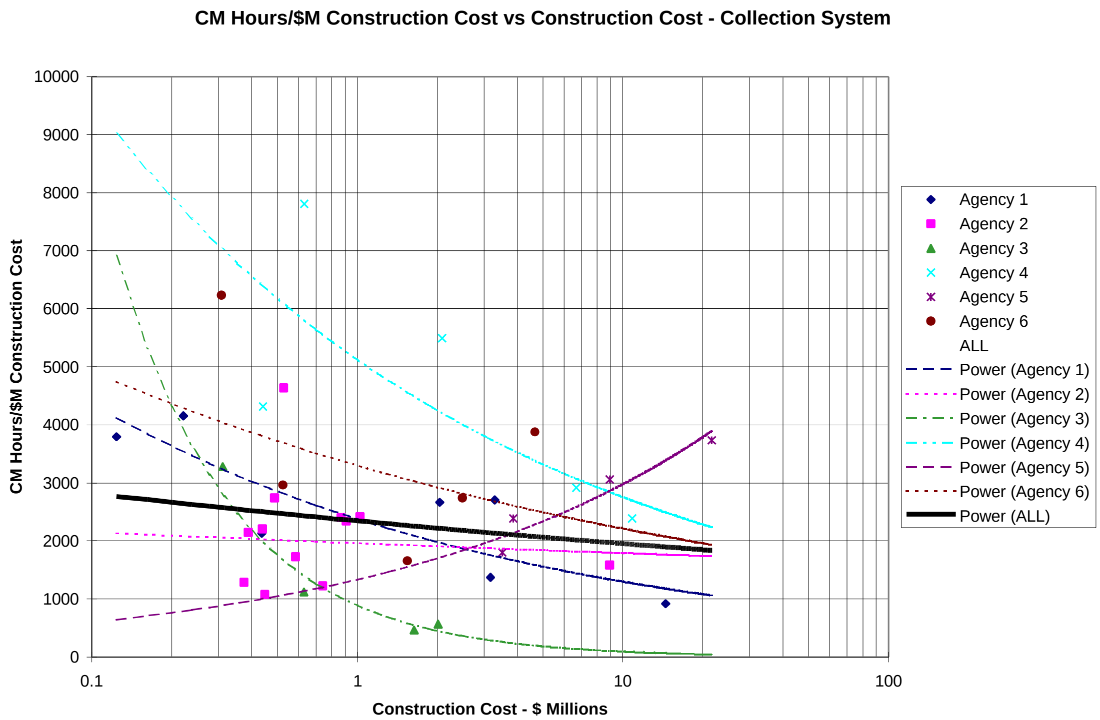


CM Hours/$ Million in Construction Cost vs. Construction Cost

There is wide variation in CM hours/$ million construction from the average curve for both plant and collection system projects, and this trend is variation is more pronounced than with design.

There is generally a downward trend for the curves for both plant and collection system projects. The downward trend for the average curve is more pronounced for plant projects than for the collection system projects.




CM Hours/$M Construction Cost vs Construction Cost - Collection System
CM Hours/$M Construction Cost
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.1
1
10
100
Construction Cost - $ Millions
Agency 1
Agency 2
Agency 3
Agency 4
Agency 5
Agency 6
ALL
Power (Agency 1)
Power (Agency 2)
Power (Agency 3)
Power (Agency 4)
Power (Agency 5)
Power (Agency 6)
Power (ALL)

Best Practices in Core Areas

The information contained in this section represents the linking of the observations from the performance benchmarking graphs and the narrative responses from the process benchmarking. The performance benchmarking graphs were reviewed and the agencies were divided into those that fell below the average line (low agency) and those that fell above the average line (high agency). The process benchmarking questionnaire responses and discussions held with the benchmarking team were evaluated for the low and the high agencies. Differences were identified and categorized into topic areas including:

- Change order management;
- Consultant procurement;
- Scope control;
- Staffing;
- Standardization; and
- Policy issues.

The topic areas and differences identified in Tables 5–10 are based on limited information, but appear to make some contribution to the efficiency differences between the organizations participating in this study. Only those topic areas included in the process benchmarking were evaluated. There may be other topic areas which differ between the agencies, but they were not included in the process benchmarking. The topic areas and differences identified below should not be relied upon to be the sole causes of the efficiency differences between agencies.

Table 5 **Change Order (CO) Management***		
Category	**Possible Explanations of Why Agencies Reported Low Change Orders**	**Possible Explanations of Why Agencies Reported High Change Orders**
Change orders limits	CO goals set for all projects. Goals as low as 3-5% were reported.	Actual COs tracked but goals not established. If goals set, not used as performance indicators.
Level of authority for change order approval	Change order approval level delegated to group managing construction. Board approval of change orders, if required, requires significant detail.	
Deferral of Change Orders	Change orders are regularly deferred to a future contract. Only non-discretionary changes completed.	Non-discretionary and discretionary changes executed with little or no concern for impact on CO goals.
Change Order Markups	15% maximum for labor, materials and equipment.	20-25% maximum for labor and 15% maximum for materials and equipment.
* This area includes the agencies efforts to maintain low levels of change orders on projects.		

Table 6 Consultant Procurement.*		
Category	**Possible Explanations For Efficiency**	**Possible Explanations for Less Efficiency**
Consultant Procurement For Small Projects	METHOD #1: Have a $150K consulting agreement streamlined process in which the consultants submit statements of qualifications (SOQs) to get on the roster. If any SOQs on roster meet project needs, selection is made from the roster. If not, a shortlist is generated from SOQs and requests for proposals (RFPs). Geared toward single discipline, can have teams put together SOQ. Any consultant can get on roster anytime. Finance group solicits SOQs and keeps roster. Updated annually for design engineers and every 6 months for construction services. Not a formal advertised process. Consultant roster allowed by recent changes in state law. METHOD #2: Use an omnibus work order process in which the agency hires a single consultant to provide a range of on call services as needed. Annual contract for consulting services Select 1 full service firm to perform various smaller project designs or several single discipline firms Total services range from $40-$160k per project	Use a traditional two step procurement process for all agreements over $20k.
Threshold limit until formal selection process required	$100,000-$150,000	$20,000

* This area includes the agencies actions in soliciting proposals, evaluating proposals, and selecting and negotiating a consultant for design engineering or construction services.

Table 6 (continued) Consultant Procurement		
Category	**Possible Explanations For Efficiency**	**Possible Explanations for Less Efficiency**
3. Agency reputation with consultants	Agency is known for having detailed scope in RFP, will make very few changes during design and does not “get in the way” of the consultants work.	Reports of consultants including and “agency factor” in the cost estimate. Consultant tends to build contingency into its original estimates knowing that agency will cut it down in negotiations.
4. Negotiating a cost ceiling.	Typical profit on design consulting agreements (total from all consultant tiers regardless of breakdown of labor and other direct costs): * Up to 250,000—10% max. * 250,000 to 2M—5% to 10% * >2M—Less than 5%	Typical profit for all consulting agreements in the 10-15% range for labor and 5% for other direct costs.
5. Procurement cycle time	Cycle time from RFQ to notice to proceed (NTP) is 2-3 months.	Cycle time from RFQ to NTP is 7-8 months

Table 7 Scope Control.*		
Category	**Possible Explanations For Efficiency**	**Possible Explanations for Less Efficiency**
Scope definition	Spend a lot of time detailing scope of work before entering into consulting agreement. O&M enhancements limited after design agreement executed or construction contracted. User preferences usually done later as separate project. If amendments for out of scope work are considered they must be justified by the requestor. Don't do them unless reasonable.	Little or no scope control and scope creeps.
Cooperation between engineering and O&M	Engineering and O&M act as one unit and both recognize that scope control is important, Both make decisions that are for the good of the agency as a whole.	Engineering and O&M view each other as adversaries. O&M needs change and are inconsistent. O&M agrees to eliminate scope during design and then gets it put back in during construction. Engineer says they will address O&M concern but it doesn't happen. O&M does not trust engineers.
Submittal Review	Engineer sends submittal copy to operations but does not wait for response.	Engineer asks contractor for 12-14 sets of copies. A lot of different people review the same document. Review comments not returned to contractor or consultant until all reviewers respond.
* As the project progresses from planning through construction the cost/scope can change with time. This area represents the efforts made by the agency to avoid changes to project scope as the project proceeds through the engineering process.		

Table 8
Staffing.*

Category	Possible Explanations For Efficiency	Possible Explanations For Less Efficiency
Use of Consultants	Ratio of Consultant Hours to Total Hours (i. e. providing services with in-house staff): Collection System Design $0-$1M: <5%. $1M-$10M: typically low but approaching 50% near the upper end of the range. Collection System CM $0-$1M: <5%. $1-$10M: typically low but increases near the upper end of the range. No significant differences noted for plant design or construction work.	Ratio of Consultant Hours to Total Hours: More reliance on consultants for collection system design and construction.
Approach to charging to capital projects	Expect 90% of capital project staff time is be billed to capital projects. Agency has overhead job number for capital project staff to charge to while working on activities which are not project related.	No overhead job number. All staff time charged to capital projects.

* This area addresses the agencies approach to staffing capital projects.

Table 9 **Standardization.***		
Category	**Possible Explanations For Efficiency**	**Possible Explanations For Less Efficiency**
Project Repetition	Significant number of repetitive type designs or similar projects.	Every project is unique.
Project Management	Less documentation and formal procedures for project management in areas of initiating, planning, tracking and managing project.	More documentation and procedures for project management.
Project File System	Each project utilizes the same project file index.	No standard file index.
* This area includes the agencies efforts towards creating systems which maintain consistency between capital projects.		

Table 10 **Policy Issues.***		
Category	**Possible Explanations For Efficiency**	**Possible Explanations For Less Efficiency**
Bid Process For Small Construction Contracts	State law allows use of construction roster. Fax scope of work, if they want to bid, send out plans and specifications. Supposed to get 3 bids. Streamlines getting bids. (Note: these actions may reduce cycle time which impacts total project costs.)	State law requires a formal bid process for all construction contracts over $20,000-$25,000.
. /WBE Requirements	No M/WBE goals or requirements. Contracts are let without any concern or effort for M/WBE participation.	M/WBE goals met or good faith efforts required on all formally bid construction contracts and consulting agreements.
Board Involvement In Capital Projects	Board involvement in project specific issues limited or nonexistent.	Board may delay project because of specific technical issues and not policy issues.
Corporate Culture	Culture supports timely decision making and moving projects to completion. Decisions are made at the lowest level and there is support at upper levels for those decisions. Staff trusts that management will support them.	Projects subject to changes and questions on scope resulting in project delays. Management does not trust staff and staff does not trust management.
* This area addresses the influence of Board mandates, management mandates or state laws which affect the efficiency of engineering on capital projects.		

Lessons Learned and Follow-up Actions

A by-product of the benchmarking process was learning what could be done to make the process more valuable and efficient. The lessons learned through this study and recommendations for follow-up actions to improve future studies are shared in the following sections.

Impacts of Inconsistent Accounting Systems

The differences among agencies' accounting systems were a significant barrier in the benchmarking effort. Overall, the result is uncertainty in the interpretation of benchmarking data. Several observations and recommendations are as shown in Table 11.

Table 11
Differences Among Agencies' Accounting Systems.

Observation	Recommendation
The level of detail in the cost template was directly limited by the accounting systems. It was necessary to have relatively few broad categories so that all agencies could compile comparable data.	Establish a recommended standard template with sufficient detail, and have all agencies move toward collection of data to fit the template.
Capital projects typically extend over a number of years. In some cases, it was difficult to compile project data when accounting systems changed during the time period.	Once a template is established, agencies should keep the framework intact over extended periods of time so that accounting over the lives of projects is consistent.
There were philosophical differences between agencies in charging time to projects. Examples include differences in whether O&M staff charge to operations or to the capital project, pressures on engineers to maintain billable ratios on projects, and how management/overhead is charged.	Standards for charging time should be set for the purposes of benchmarking. Each agency should be able to maintain their own philosophy, but accounting systems should be set up to allow adjustment of cost data to fit the standard for purposes of benchmarking.
Collection of cost data was labor intensive for some agencies.	Establish a standard template and adjust accounting systems to fit the template.

Detailed Layers for Each Project Phase

As a result of conducting this benchmarking study, it has become evident that accounting practices in many of the agencies are not providing sufficient detail for management and comparison of the CIP programs. In the initial stages of the study, the group began to develop a very detailed template to capture project costs. After review of the data that was available to them from their respective financial systems, the template had to be modified to account for the lack of cost accounting details. The cost information had to be grouped into three basic categories: planning, design, and construction costs. Individual agencies had more detailed cost information on these areas, but none could have gathered all the cost information for a detailed template as the agencies would have liked.

A more detailed template is presented in the Appendix for use in further benchmarking efforts. Individual agencies are making changes to their respective accounting practices to be able to capture more detailed project cost information in the future. The benchmarking group would like to see the template used as a guideline for future benchmarking efforts.

Evaluating the Agencies' Motivation to Change

The agencies' reasons to use this benchmarking system as a motivation to change are derived from several interrelated factors. The motivating factors and the stimuli for change are listed below.

Cost Competitiveness: The wastewater agencies involved in this benchmarking effort all operate in a business climate where there is considerable interest in or pressure to be competitive with other similar agencies and private industry. One stimulus is the continued interest from private wastewater operations firms to solicit operations contracts for large facilities. The capital improvement programs of the agencies are logical extensions of privatized wastewater operations for contractors that offer a full range of services to local governments. Another stimulus for the agencies to be cost competitive is related to ratepayer and taxpayer perception of government costs, explained below. It is the expectation of each governing body that its agency will provide cost-effective and cost-competitive services so that the ratepayer or taxpayer receives the best value for every dollar spent.

Ratepayer and Taxpayer Perceptions of Government Costs: Citizens are, and will continue to be, focused on the cost of service when the service is provided by local government. Stories of government inefficiencies have produced the perception that public agencies may not be good stewards of the funds generated from rates and taxes. This factor may not be so much a stimulus for change as it is a stimulus for proving that the agency's performance and processes are competitive. The capital engineering benchmarking methodology established in this body of work offers a tool for beginning to measure and assess the agency's performance on each project.

Real or Perceived Inefficiencies: Agency stakeholders and managers may have questions about how certain parts of their capital programs are performing. The questions may be generated by previous experience, or by analyses of this benchmarking data. In either case, this benchmarking work gives a snapshot of comparable practices and performance which begins to answer questions regarding agency effectiveness and efficiencies, and may provide a stimulus for change.

Continuous Improvement: The project benchmarking provided in this text is mainly valuable as a starting point. The search for best practices and best performance related to capital projects has begun. The information provided in this report is another stimulus for change when it is integrated into a cycle of continuous improvement. Agencies may choose to act on the project benchmarking methodology and data provided in this report by:

- Inputting more project data so that a representative set of projects is used to set the benchmarks;
- Determining current "gaps" in practices or performance (i.e., where the agency needs or wants to change and improve);
- Projecting future goals or performance levels;
- Communicating and gaining acceptance of the future goals;
- Adopting the new goals;
- Developing and implementing strategies and actions to meet the new goals;

- Measuring performance and progress; and
- Reassessing or recalibrating the benchmark.

Benchmarking Time and Budget Commitment

After going through the process, it is suggested that organizations establish the expense they are willing to absorb, identify what information they expect to receive, and determine how the information gathered will be used, before they embark on an effort to benchmark. They also need to ensure that the other member organizations envision similar efforts and expectations, so that the work can be spread equally among the group members. Fortunately in this study, the groups involved had similar expectations and commitment. This up-front planning is necessary so that reasonable estimates of time and budget for the benchmarking process can be established.

The purpose of this section of the report is to identify the actual activities, actual durations, and actual manhours spent in performing this benchmarking study. This information should prove useful for other agencies or these same agencies if they should decide to go through a similar process in the future. Of course, if a group was to use the approach described in this report, the level of effort and time required could be reduced because approximately 30% of the time spent involved preparing the template and questionnaires. Table 12 indicates the actual effort expended in performing this study.

Table 12 Actual Engineering Benchmarking Effort			
Activity	**Activity Duration**	**Average Hours For Each Activity* (Per Group Member)**	**Total Hours For Activity (Per Group Member)**
Full Group Meetings (8 total)	1 meeting every 45 days	8 hours per meeting plus travel time and expenses	64 hours (not including travel time)
Meeting Preparation	1 day	8 hours per meeting	64 hours
Process Benchmarking	2 days-prepare questionnaire 5 days-prepare response to each questionnaire 2 days-review and consolidate responses	72 hours per questionnaire	144 hours (assuming 2 questionnaires per person and 12 total)
Performance Benchmarking	1 day-gather data per project* 5 days-create database and graphs 5 days-input project data 3 days-revise data 3 days-revise graphs	8 hours per project to complete template 100 hours for database/graph creation and revision	96 hours (assuming 12 projects per agency) 100 hours (this was done by a consultant)
Report Writing	1 day to write assigned sections ½ day to incorporate comments 1 day-technical writer coordinate sections	12 hours to create assigned report sections 8 hours to finalize each group members report sections	12 hours 16 hours (assuming each group member has 2 report sections)
Totals	1 year		496 hours
* Some agencies took longer, depending on the accounting system.			

Incorporating Data From Private Firms

The Benchmarking Phase II Engineering Work Group had access to four documents that examined and compared engineering processes and costs. These were:

1. The *Benchmarking Public Sector Engineering Services Report* prepared by MARRS Services, Inc., in 1996.
2. The *Project Management Benchmarking Study* sponsored by the Project Management Institute and conducted by the Civil Engineering Department at the University of California at Berkeley.
3. *City of San Diego CIP Performance Indicators*, November 1997.

4. The *ASCE Consulting Engineering: A Guide for the Engagement of Engineering Services*, Manual No. 45, 1981.

The laws in their respective jurisdictions constrain all the agencies participating in this benchmarking study to competitive public bidding of capital projects, with the contract awarded to the lowest responsive and responsible bidder. Although the benchmarking study focuses on differences, this situation makes the agencies more similar than not in the manner in which they prepare contract documents and manage construction.

Further benchmarking work could be done incorporating information from private firms that do not share the same constraints. If practices such as design-build or allowing only select bidders to tender a bid could be compared with conventional agency practice, it might provide information that could lead to changing the bidding laws.

Additional Process Benchmarking Topics

The agencies realized during the course of this study that additional process benchmarking topics should be considered in future studies. The results of exploring these future areas may aide in assessing process and performance benchmarking.

Possible future topics are:

- Personnel issues;
- Technology Issues;
- Quality Assurance /Quality Control (QA/QC);
- Testing and Start-up Process and Procedures;
- Plant Automation; and
- Design-build.

Personnel Issues

Table 13 shows the areas that he agencies identified for consideration under this category.

Table 13
Personnel Issues.

Personnel Issue	Possible Questions or Areas of Investigation
Performance Evaluations	Are they done? Frequency of evaluations?
Compensation	Civil Service, Merit, Bonus, Incentive, Broadbanding, Salary Steps
Training	Is training program established, monitored, maintained, mandatory, optional?
Union	Do employees belong to a union? Which employees belong to a union?

Technology Issues

The increased use of technology is continuing to affect the way business is done. Suggested areas to research might include:

- Use of the internet and intranet for communication and research;
- Use of a project specific website for project communication;
- Use of scanning as an effective means to store and record documents; and
- Use of equipment for field imaging.

Quality Control and Quality Assurance

Capital improvement construction costs might be impacted by the way agencies address Quality Assurance QA/QC. QA is the act of assuring or monitoring quality control. The primary questions of interest in this area might be:

- Who performs QC (Contractor or Owner)?
- Who performs QA (Owner or Outside Agency)?
- Is the agency's QA/QC program effective?
- How extensive is the QA/QC program?

Testing and Start-up Process and Procedures

The level and detail of testing and start-up of new equipment should be considered in future benchmarking efforts. Questions that could be explored are:

- Who performs the testing and start-up function; and
- Is the testing and start-up procedure different based on equipment type or impact to plant operation?

Plant Automation

The degree of plant automation was not addressed in this study. It is suggested that a comparison be made of all activities, functions and processes to determine whether similar functions are automated or manual.

Design-Build (Alternate Capital Delivery System)

While alternate capital delivery systems were part of the process benchmarking effort, as noted in the summary section above, there was limited experience in the area of design-build projects. Future benchmarking efforts should further explore the benefits and experiences with design-build projects.

Categorizing Change Orders by Cause

One of the unexpected results of the benchmarking study was the Design Cost/Construction Cost Versus Change Order Percent graph. Participants assumed that an increase in design cost would result in a decrease in change order percentage. The graph did not support this assumption.

This outcome surprised the participating agencies. The results are contrary to what was thought to be an obvious correlation. It was believed that a primary factor in reducing change orders was a better design effort. While is it recognized that a perfect design is not possible or practical, it was believed that change order percentage would be reduced by design effort.

Participants still theorized that an increase in design cost should result in a decrease in change orders, particularly with change orders attributable to design improvements and oversights. It is also possible that change orders related to unforeseen site conditions could decrease with increased design cost.

In order to confirm this assumption, is it recommended that change orders be classified into the six categories identified below. It is further recommended that change orders be plotted by individual category as a function of design cost in follow-up studies. This categorization will provide the data necessary to further understand the effects of increased design effort on change orders. In addition, the complexity of the project should be taken into consideration when reviewing design effort and change orders.

The suggested change order classification categories are described as follows:

Design Improvements: During the course of construction, the contractor, maintenance personnel, or design personnel may identify products or designs that create improved operational characteristics. An example would be a change that reduces maintenance costs. During a protracted design period, technology advances occur that may not be incorporated in the design documents, but are incorporated during construction by change order.

Design Oversight: Most contract drawing and specifications are so complex that they contain a number of design oversight issues. Examples of design oversight might be incorrect information given to the designer; insufficient time available to research all details associated with a large job, or human error.

Unforeseen Site Conditions: During the course of construction, the contractor may encounter conditions unknown at the time of design. The most common example is “unsuitable material” (such as poor soil conditions) encountered while building a road. Other examples include buried utilities encountered while excavating for a new building, new utility, or new pipeline.

Operational and Maintenance Repair: During the course of construction, failed or failing equipment may be encountered. A typical example in a wastewater treatment plant would be an existing valve which due to old age is found to be near failure or inoperative due to heavy corrosion (rust) on the inside of the valve. It might be necessary to close this valve to perform contract work on connected piping, but this work cannot proceed until this valve is repaired or replaced.

Construction Incentive Change Proposal (Value Engineering): Contractors are always encouraged to utilize their construction expertise to improve contract performance and thereby create an overall reduction in the total cost of the contract. An example is the need to specify the method or sequence of construction to minimize the impact on an operating sewerage treatment plant. If the contractor is able to identify a method or sequence of construction that still permits the plant to operate but also reduces the cost of construction, the county and the contractor will share in the savings.

Claims and Disputes: Claims and disputes are common in construction. Contractor claims for extra compensation often arise from disputes. Typical claims are delay claims and loss of productivity claims. Disputes arise when a difference of opinion occurs as to interpretation of the contract documents. Disputes generally result because there is more than one way to interpret a drawing or the written word. Such disputes tend to be difficult to resolve and often require the intervention of mediators, dispute review boards, or litigation.

Appendix

PERFORMANCE BENCHMARKING FOR ENGINEERING - CAPITAL PROJECTS

TEMPLATE FOR TOTAL PROJECT ENGINEERING COSTS AND HOURS OF EFFORT

Agency: ____________ **Project Name:** ____________

Project Type: ____________ **Rehab vs. New Index:** ____________

Description: ____________

	ENGINEERING SERVICES				OTHER	PHASE TOTALS		
	IN-HOUSE LABOR		CONSULTANT		DIRECT COSTS	COSTS		DURATION
	(Hours)(1)	($)	(Hours)(1)	($)	($)	(Hours)(1)	($)	(Months)
PLANNING								
Supervision/Admin.	300	25,000	1,500	300,000	1,000	1,800	326,000	
Clerical								
Legal								
Planning Phase Management								
Initial Studies/Proj. Planning								
Facilities Planning								
Project Development								
R&D								
Special Studies								
Surveying/Testing								
Drafting								
Geotechnical Investigations								
Modeling								
Reviews								
Mitigation Costs								
ROW/Land Acquisition								
Permits								
Environmental Documentation								
Public Relations and Commun.								
Admin & General Expenses								
Planning Total	300	25,000	1,500	300,000	1,000	1,800	326,000	8
DESIGN								
Supervision/Admin.								
Clerical								
Legal					5,000		5,000	
Design Phase Management								
Design								
Preliminary Design								
Engineering								
Drafting								
Geotechnical								
Survey	500	80,000				500	80,000	
Modeling								
Testing								
Review								
Final Design								
Engineering								
Drafting								
Geotechnical								
Survey								
Modeling								
Testing								
Review			500	250,000		500	250,000	
Equipment Purchase								
Mitigation Costs								
ROW/Land Acquisition								
Permits								
Environmental Documentation								
Public Relations and Commun.								
Bid & Award								
Admin & General Expenses								
Design Total	500	80,000	500	250,000	5,000	1,000	335,000	12
CONSTRUCTION								
Supervision/Admin								
Clerical								
Legal								

PERFORMANCE BENCHMARKING FOR ENGINEERING - CAPITAL PROJECTS

TEMPLATE FOR TOTAL PROJECT ENGINEERING COSTS AND HOURS OF EFFORT

Agency: ______________________ **Project Name:** ______________________

Project Type: ______________________ **Rehab vs. New Index:** ______________________

Description: ______________________

	ENGINEERING SERVICES				OTHER	PHASE TOTALS		
	IN-HOUSE LABOR		CONSULTANT		DIRECT COSTS	COSTS		DURATION
	(Hours)(1)	($)	(Hours)(1)	($)	($)	(Hours)(1)	($)	(Months)
Construction Phase Management								
Engineering Services								
RFI Processing								
Submittal Processing								
Progress Payment Processing								
Schedule Review & Comment								
Claims Resolution								
As-Builts Development								
Contract Management								
Inspection								
Surveying								
Materials Testing								
Safety								
Commissioning								
Testing and Startup								
O&M Manuals								
O&M Training								
Control System Programming								
Close-out								
Warranty								
Mitigation Costs								
ROW/Land Acquisition								
Permits								
Environmental Documentation								
Public Relations and Commun.								
Admin & General Expenses								
Construction Total								24
PROJECT TOTALS						2,800	661,000	44

CONSTRUCTION CONTRACT COSTS	
AMOUNT OF CONSTRUCTION CONTRACT ($)	29,524,000
COST OF OWNER PROCURED EQUIPMENT ($)	5,875,000
COST OF CHANGE ORDERS ($)	2,345,000
COST OF HAZARDOUS MATERIAL MITIGATION ($) [if not included in Construction Contract]	500,000
TOTAL CONSTRUCTION COST	38,244,000

Notes: (1) Italicized values are estimated hours.