How to Accelerate Design and Construction for Large Water Supply Projects

By

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For much of Texas, the drought of 2011 is the most severe one-year drought on record. Climatologists predict the drought will continue for the foreseeable future. Additionally, Texas continues to grow rapidly in many metropolitan areas. These and other factors put pressure on existing water supplies to meet demands. In response, some water suppliers have been forced to develop new supplies on an emergency basis. The compressed schedule of design, permitting and construction offers many challenges to the designer, owner and builder.

This paper offers concepts for expediting the planning, design, permitting, survey, land acquisition and construction of water supply projects. A comparison of the critical path for a normal schedule and expedited schedule is presented for water supply projects. The comparison presents potential solutions to expedite the project schedule, including the following:

- Alternate procurement methods for major equipment items
- Alternate delivery methods for construction including Design-Bid-Build, Design-Build and Construction Manager-at-Risk
- Splitting the project construction contracts to expedite construction
- Survey and easement acquisition for speed
- Design concepts to expedite environmental permitting of intake structures and pipelines
- Project management of planning, design and construction
- Technology tools for managing design and construction

This paper will also provide case studies and lessons learned from three fast-track water supply projects in Texas:

- Project A: Design and construction of a 156-mile pipeline, 7 pump stations, 5 electric substations, a 100 million gallon storage reservoir and other facilities in 38 months
- Project B: Design, permitting and construction of a new surface water supply including a 30-mile pipeline, intake pump station and booster pump station in 27 months
- Project C: Design, permitting, and construction of a new groundwater well field, 65 miles of pipeline, and four pump stations in 18 months

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Introduction

National Climatic Data Center records indicate that 2011 was the driest year and second hottest year in Texas for the 117 years of record data. The 2011 statewide average of 11.18 inches of rainfall eclipsed the previous low record of 13.91 inches. The annual statewide average rainfall is 29.11 inches. Most of Texas experienced more than 50 days of 100-degree heat, and many areas experienced more than 100 days. The lack of rain and high temperatures has been brutal to water supplies. Additionally, climatologist say the drought could last into late 2012 due to the La Niña effect.

Drought is not the only hazard to water suppliers. One North Texas supplier lost 25 percent of its water supplies when zebra mussels were discovered in a source lake, causing the US Army Corp of Engineers (USACE) to shut down water transfers for over two years. Another supplier lost a large supply lake for several months, when a gasoline pipeline ruptured and spilled thousands of gallons of MTBE into the lake. Another supplier’s lake was heavily contaminated by natural salt, when a flood caused an upstream natural brackish lake to spill for the first time in history. With the ongoing water wars in Texas and the southwest, the possibility of judicial action to curtail water supplies is also a real threat. All of these conditions could force water suppliers to develop emergency water supplies on an accelerated schedule. This paper offers concepts for expediting the planning, design, permitting, survey, land acquisition and construction of water supply projects. Three case studies are also presented.

The Critical Path for Normal and Accelerated Projects

Figure 1 shows the critical path for a normal water supply project. The planning phase typically includes a brief study of alternative conveyance systems, treatment methods, funding, phasing, ownership and operations structure, and permitting requirements. The planning phase often includes political decisions and buy-in of the rate payers. For these reasons, it is difficult to accelerate the planning phase. To the extent feasible, water suppliers should identify future water supplies and lay the ground work for project development before an emergency arises. By doing so, critical time and money may be saved.

During the conceptual design phase, the size, capacity, location and operations protocol are determined for the water supply. These items are needed to further define the project scope and cost, and to permit land and permit acquisition. Land acquisition requires right-of-entry, surveying, appraisals and real estate negotiations. Permitting may include USACE Section 10 and 404, NEPA, water rights, and many other state and local permits. After the land and permits are acquired, the final design phase, bidding, construction and system commissioning occur.
Figure 1 – normal schedule

Figure 2 shows the critical path for an accelerated water supply project. Note that the conceptual design phase overlaps the planning phase. Many conceptual design activities can begin as soon as major political decisions are made. For instance, desktop pipeline route studies and conceptual intake design studies can begin when the starting and ending points for a conveyance system are determined. Also, note that the land and permit acquisition phase can begin as soon as the planning phase is complete and the conceptual design phase is underway. Right-of-entry, boundary surveying, aerial topographic surveys, and environmental studies can begin as soon as a major portion of the project footprint is determined. The final design phase can be concurrent with the land and permit acquisition phase, once the project footprint is finalized and the critical design features, such as wetland crossings and water intakes are established. Again, bidding and construction follow the final design phase for a typical Design-Bid-Build delivery method.
### Figure 2 – Accelerated Schedule

**Concepts to Accelerate the Planning Phase**

One of the best ways to expedite the planning phase is to have an experienced engineer and a decisive owner. An experienced engineer who knows the owner’s preferences can eliminate many steps that are not important to the owner. Schedule, performance and cost are competing criteria. For most projects, the owner can get priority on two of these three criteria. Rarely can the owner get all three. Knowing the owner’s value system will help the engineer get to the preferred solution the quickest. A decisive owner will have the confidence to make major decisions without exhaustive levels of analysis on each decision point. Decisive owners don’t change decisions when the discussion changes from schedule to cost or performance. Decisive owners have strong leaders that will build consensus on the owner’s team.

**Concepts to Accelerate the Conceptual and Final Design Phases**

The low hanging fruit to expedite the design phase includes the use of standard designs that the owner accepts. Other concepts include doing a resource schedule analysis to determine the number of design teams required to meet the schedule. The project should be split into logical segments that can remain separate through design and construction. This might include splitting pipelines, pump stations, reservoirs and other facilities into manageable segments throughout the design and construction phases. This allows each team to have specialists such as surveyors, design engineers, environmental scientists, land agents and owner personnel to focus on smaller components. This approach also minimizes the need for coordination across the teams.

GIS can expedite many design tasks such as route selection, environmental studies, cost analysis, land acquisition tasks and mapping. Aerial topographic surveys can be used to expedite field
work, since they require only limited field access for setting control points. Web tools can facilitate communication, reporting, file sharing, construction bidding and construction submittal processing. Civil 3D can expedite drawing production, once the drawing standards are established.

**Concepts to Accelerate the Land Acquisition and Permitting Phase**

To the extent feasible, the project should be designed to eliminate triggers for USACE 404 and Section 10 or state environmental permitting requirements. This may require innovative designs that minimize disturbance to jurisdictional waters. Other permitting triggers may include threatened and endangered species habitat and bottomland hardwood forests.

The owner should develop a methodical land acquisition strategy that will meet the schedule requirements. This may require more land agents, less time between offers, and less time for negotiations. One of the keys is to keep landowners informed and be professional with all communications. In the end, the owner has to balance the needs of the project with treating the landowners with as much patience as time permits.

It is very difficult, and nearly impossible, to expedite acquisition of land from State and Federal bureaucracies. The owner’s best option may be to avoid these properties.

**Concepts to Accelerate the Bidding and Construction Phase**

The following are design concepts to help expedite construction:

1. As previously mentioned, the design team should do a schedule analysis to identify the construction critical path and long delivery items, and divide the construction into smaller manageable components that can be constructed simultaneously. Schedule float time between construction contracts to allow for inevitable delays.
2. To the extent possible, the design should allow modular construction that requires less field coordination and customization.
3. The design should include readily available, locally provided construction materials to prevent delays for shop drawing approvals and shipping.
4. The design should allow simple construction that is heavy on materials and light on field labor. An example of this is to design with larger concrete beams and slabs with less forming, reinforcing and construction joints.
5. To the extent possible, the design should minimize below-ground construction requirements. Below-ground work often precludes multi-tasking construction activities and is subject to weather delays. An example is above-grade piping in structures rather than below-grade piping.
6. Prefabricated materials, such as wall panels, precast concrete structures and skid-mounted process units, should be used to allow more efficient shop fabrication.
7. The design should be flexible to allow innovative construction methods.
8. Standard equipment should be used where feasible. Customized equipment that requires vendor design, special fabrications, specialized materials of construction and specialized factory testing can add time to deliveries.

9. The design should consider testing and start-up requirements. Process controllers should be factory tested to prove-out control logic. Connections to existing facilities should be designed to accommodate water filling, draining and testing. Temporary electric power may be necessary for field check-out of equipment. The design should allow sub-components to be tested prior to start-up of the entire system to prevent delays.

10. The design team should consider third party schedule risks, such as delays in permanent power, utility relocations by others and conflicting projects by others. Develop a contingency plan to mitigate risk.

11. Use electronic distribution of bidding documents to expedite the bidding process.

12. Use web technology for processing construction submittals.

Alternate Project Delivery Methods

The state laws vary for delivery of design engineering and facility construction. Design-Bid-Build (DBB) is the conventional approach that is standard in the water supply industry. Design-Build (DB) and Construction Manager-at-Risk (CMAR) are allowed to some extent in many states.

Design-Bid-Build

With DBB, the owner hires an engineer to prepare bidding and construction documents, takes bids for the construction and materials, then executes a contract with a contractor for the construction phase. DBB is the conventional delivery method, since it shifts most of the financial and schedule risk to the contractor. DBB provides very competitive pricing, but it is the slowest delivery method.

Design-Build

With DB, the owner hires an engineer to develop preliminary design and bidding documents (typically 10 – 30 percent complete), then takes bids from design-build teams for final design and construction. DB is available in many states and is becoming more common in the water industry.

DB can reduce delivery time compared to DBB, since it allows the design and construction phases to overlap and the DB team can be more innovative. However, the process of selecting the DB team can add two or three months to the schedule. If the critical path for the project schedule is controlled by the planning, land and permit acquisition, and construction, then DB may not be faster than DBB. DB should have fewer change orders than DBB, since the DB team has singular responsibility for design errors and omissions. One disadvantage of the DB process is that the owner loses control of the design after the DB team is selected. Additionally, the
owner should hire a construction manager or use in-house forces to represent the owner’s interest during design and construction, since the DB engineer is an advocate for the DB team.

**Construction Manager at Risk**

With CMAR, the owner hires an engineer to design the facilities and a CMAR to act as a general contractor for construction. The CMAR assists the owner and engineer during the design phase with design reviews, innovations, and management of cost and schedule. The CMAR hires vendors and sub-contractors or self-performs construction components. The owner can require a guaranteed maximum price (GMP) at any stage of design. The GMP includes a contingency which may or may not be shared between the CMAR and owner.

CMAR offers many of the advantages of DB, without some of the disadvantages. CMAR can reduce project delivery time, since it allows the design and construction phases to overlap and the CMAR can offer ideas for innovation. Unlike DB, the CMAR process does not require additional time for CMAR selection, which can be concurrent with other activities. Unlike DB, CMAR allows the owner to retain control of the design. The CMAR process should result in higher quality than DB or DBB, since the owner can control sub-contractor and vendor selection. The CMAR process should have fewer change orders than DBB, since the CMAR has been involved with the design and reviewed the bidding documents.

**Alternate Procurement Methods**

The conventional method of procuring equipment and construction is through DBB. For major equipment with long delivery, this method may add time to the overall project completion. Alternate procurement methods may include pre-selection and assignment or owner furnish. With pre-selection, contracts for long delivery items are solicited early in the design phase. Purchase orders are awarded to the selected equipment vendors, and the purchase orders are assigned to the general contractor after the construction contract is awarded. With owner furnished equipment, the same process is used, except the owner retains the purchase order. One disadvantage with both of these methods is that the owner retains some of the contractual risk for late delivery or deficient equipment, since he did the original selection of the vendor. With the CMAR process, pre-selection of the equipment is through the CMAR; therefore, the owner has less contractual risk of late delivery or deficient equipment.

Competitive Sealed Proposals (CSP) is allowed in some states and offers some advantages to owners for equipment and construction procurement. With CSP, the owner makes a value based selection of the equipment and/or construction contractor rather than selecting the lowest among qualified bidders. With CSP, the owner can establish selection criteria such as cost, time, qualifications, experience, claim history, safety and equipment performance. The owner should specify the selection process and rating system to the bidders. CSP allows the owner to pick contractors and vendors with a record of finishing projects on time. Additionally, CSP helps to
raise the bar on the whole industry, since it will tend to weed out suppliers and contractors that perform at lower levels.

**Case Study – Project A**

Project A included the following metrics:

- 75 million gallon per day (MGD) lake intake pump station
- 75-MGD booster pump station with 6-MG storage tank
- 30 miles of 60-inch and 54-inch pipeline
- $98 million construction cost in 2008
- Original schedule – 22 months from start of planning and design to delivery of water
- Actual schedule – 25 months from start of planning and design to delivery of water

The following concepts that were used to expedite Project A:

- Portions of the pipeline were routed along roads and properly lines to expedite easement acquisition and construction.
- Large valves, pumps and variable frequency drives were ordered during the preliminary design and assigned to the contractor.
- The pipeline contracts were bid early to allow the easement acquisition to be concurrent with the pipeline bidding process, pipe raw steel delivery, processing of pipe shop drawings and initial pipe fabrication.
- The pipeline route was selected to avoid jurisdictional wetlands and archeological sites that would have triggered USACE 404 permitting and extensive archeological investigations.
- The lake intake structure was designed to tie into an existing intake structure owned by another utility. This allowed all of the intake pump station construction to be constructed outside jurisdictional waters, which allowed a Nationwide 12 USACE 404 permit.
- The intake pump station sump was constructed with a circular shaft and micro-tunnel intake pipe, reducing construction time. Additionally, this sump was bid early under a separate construction contract, so that it could be constructed concurrently with the design of the pump station.
- The 30-mile pipeline was split into three sections and bid simultaneously to meet the construction schedule.
Project A – Sump Pit

Project B

- 156 miles of 60-inch and 53-inch pipeline
- One intake pump station and 6 booster pump stations
- Five steel storage tanks each with 6 to 8 million gallons capacity
- 100-MG terminal storage reservoir
- Seven electric substations
- 15 major equipment delivery contracts
- System initial capacity of 65 MGD and ultimate capacity of 90 MGD
- Original schedule – 36 months from start of design to delivery of water
- Actual schedule – 38 months from start of design to delivery of water

The following concepts were used to expedite Project B

- The planning studies, 404 permitting and route selection were performed prior to the emergency, thus saving time.
- The pipeline contracts were bid early to allow the easement acquisition to be concurrent with the pipeline bidding process, pipe raw steel delivery, processing of pipe shop drawings, partial pipe fabrication and manufacture of a massive rock trenching machine. The bid was structured to allow a new pipe production plant to be located near the job site, although the successful bidder chose to use existing remote plants.
- The pipeline was designed to allow innovative high performance trenching and backfill processes. This included rock trenchers, vibratory sieves for processing native
embedment, and embedment roller compaction equipment. One pipe-laying crew averaged over 2000 feet per day, and the crew laid over 5000 feet on many days.

- Modular construction was used for many of the facilities to expedite construction.
- The electric power lines were constructed by the owner, to bypass the need for a Certificate of Convenience and Necessity (CCN) Permit.

*Rock Trencher, Vibratory Sieve and Compaction Wheel used for Project B*
Case Study - Project C

Project C included the following metrics:

- 45 miles of 48-inch and 42-inch transmission pipeline
- 22 miles of 10-inch to 36-inch well collection pipelines
- 21 groundwater wells
- Three booster pump stations at 25-30 MGD each
- Two ground storage tanks – 2- and 6-MG capacity
- $130 million construction (2012)
- Original schedule - 18 months from start of planning and design to water delivery
- Actual schedule – currently under construction and on schedule

The following concepts were used to expedite Project C:

- The pipeline was routed along existing pipelines and roads to expedite easement acquisition
- The pipeline was bid early to allow easement acquisition to be concurrent with bidding, raw steel delivery for pipe production, processing of pipe shop drawings and mobilization.
- Two pipeline contracts were bid with a provision that the bidders could offer a deduction if awarded both contracts. The successful bidder offered a $3.6 million deduction.
- CMAR was used for the pump stations. Long delivery items were purchased through the CMAR, including pumps, valves and variable frequency drives. CSP was used for the CMAR selection, and all equipment and construction contracts.
- The pump stations were split into below-slab and above-slab contracts to allow the underground construction to be concurrent with design of the above-grade facilities.
- The pipeline was designed to use native materials for bedding and backfill to expedite construction. One four-mile segment of the pipeline crossed through shifting sand dunes. On-site mixed flowable fill with native materials, flyash and cement was specified for this segment.

Conclusion and Summary

Design and construction of water-supply projects are challenging in normal times. When projects must be accelerated to meet emergencies, many additional challenges are presented for the owner, engineer and contractor. The normal processes for design and construction will not be effective for an accelerated schedule.

The engineer should do a detailed evaluation of the design and construction schedule to identify means for acceleration. The schedule for an accelerated project should be controlled by the planning, land and permit acquisition, bidding and construction phases. Accelerated schedules
may require splitting the project into small manageable components. The construction phase schedule should be controlled by long delivery equipment items or material delivery limits. In other words, the equipment should be ordered early enough in the design phase to prevent project delays, and the construction should be split into small enough segments to meet this schedule without overloading material manufacturing limits.

The engineer should select a design to expedite environmental permitting and land acquisition, where applicable. The designer should route around environmental obstacles (permitting triggers) and pick pipeline routes that are reasonably acceptable to landowners. Innovative designs may be needed to avoid USACE 404 permitting notifications.

The use of alternate delivery methods, especially CMAR, may allow the owner to expedite construction, order long delivery items early and still maintain control of the design. CSP allows owners to use a value based selection of vendors and contractors, which can decrease construction time and increase quality.

The use of technology may expedite projects, including aerial topographic surveys, GIS (route studies, environmental studies, and mapping), Civil 3D for drawing production, and web technology (bidding, file–sharing, communication and construction submittal processing).

One of the keys to meeting an accelerated schedule is to have an experienced engineer who is familiar with the owner’s value system. Another key is to have an owner with strong leadership that can make quick decisions and develop consensus on the owner’s team.