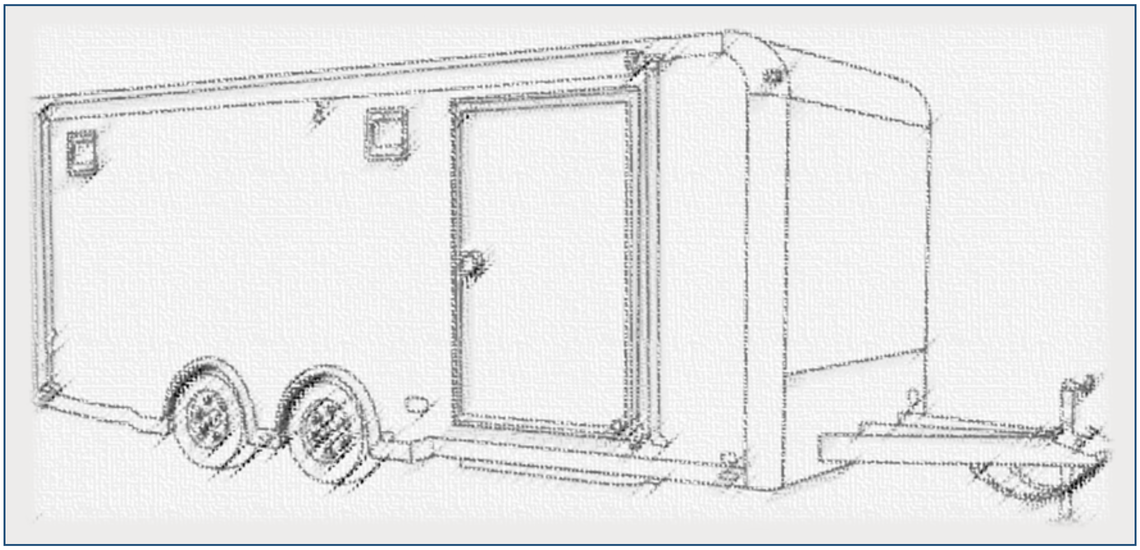
Mobile Station Feasibility Study

Proof of Concept



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Date

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1. Abstract

Objective

The intent of this *proof of concept* document is to, 1) determine if a mobile monitoring station can be built to provide needed water quality data, at a reasonable cost, and if so, 2) provide specific planning and design guidelines as a reference for mobile station construction.

Figure 1. Example of mobile water quality monitoring station.

Approach

Using experience gained building and working in permanent stations, Municipal Water Quality Investigations' (MWQI) staff understand what is required to fabricate and operate a station. The mobile station concept is similar enough to a permanent stations that MWQI is distinctly prepared to assess the viability of mobile stations. In this document, the required *component systems* specific to a mobile station have been evaluated in detail. Furthermore, the interplay between component systems and how they regulate one another, are analyzed to determine if a station can be designed, built, and implemented in a cost effective and functional manner.

Results

Based on this research, building a mobile station is possible, and more so, a mobile station can be built cheaper than a comparable permanent structure.

A mobile station can be constructed using a trailer with a permanently mounted generator and battery bank for a power supply, and a small removable shelter to house the analytical equipment. Such a station can be used to gather water quality data from areas of interest around the Delta and State Water Project as long as the sites are accessible by a Class C truck and tandem axle trailer. The same station and trailer combination can be parked on a barge, over a body of water, to gather water quality data. Once the needed data has been collected, the station can be redeployed to a new location. If data from a particular site is determined valuable enough to warrant a permanent fixture, the shelter can be anchored to a concrete slab and connected to the power grid. The mobile station designs assessed in this document can conform to California building and energy compliance codes.

At the time of this report, the total cost for a viable, fully outfitted mobile station is roughly $242,000. This includes all of the instrumentation and peripheral equipment that would be required for operation. Taking into account the cost of instrumentation, this amount is well less than what the MWQI program has spent on permanent water quality stations in the past.

Most manufacturers have a minimum of 6 weeks listed as a production schedule, with some as much as 12 weeks after the customer approves of the drawings and the purchase order is accepted. This is still far less than the time needed to construct a permanent building.

2. Introduction

Developing an understanding of the hydrology and conditions of California's waterways is essential to protect the health of ecosystems and to improve water quality and flows for municipal and agricultural uses. Knowledge and understanding is built upon data. Monthly or weekly grab samples provide data, but not nearly at a high enough resolution to identify changes in the Delta and accurately determine the fate of key constituents in the State Water Project (SWP). High-frequency data, made available in real-time, can improve the knowledge base by providing water managers a robust and readily available data set.

In the past, high-frequency, continuous data stations (real-time stations) have been housed in existing SWP buildings, or shelters specifically constructed for the purpose of real-time monitoring. The location of MWQI's early real time stations coincided with existing structures, but more recent data requests have been for locations where no infrastructure exists. MWQI's experience building permanent stations has shown that the cost of construction can be high. If the site is an ideal location, the cost of construction is simply a part of getting the needed data, if the construction is done at a reasonable price. If the location is questionable-- in terms of data quality-- the time and construction costs may make the project unwarranted. These potential risks beg the question: Can real-time water quality data be provided in a more time and cost effective manner?

This is the question that lead MWQI to develop the portable station concept. The hypothesis is that a portable monitoring station could house the same equipment as permanent stations, without the time and monetary commitment associated with constructing a permanent building.

Furthermore, a properly designed mobile station could be converted to permanency if the temporary location was deemed worthy. If a permanent structure was unnecessary, the mobile station could be relocated to a more viable site. This flexibility would also allow a station to be moved around to pinpoint the best monitoring site within a given area, such as checking both banks downstream of a blending area or near a check structure along the Aqueduct. This same station configuration could also be parked on a barge over a body of water to gather data along transects or vertical profiles, or used to monitor water quality on a temporary basis where restoration work or an infrastructure project was being constructed. Another possible use for a portable station is during emergency response. In the event of a levee breach, chemical spill into the Aqueduct, or major flood, the mobile station could be set-up quickly to collect data. The data can then be used to make decisions about pump-out, blending, clean-up, and potential hazards to human and ecosystem health.

Really, the possible uses for a mobile station are numerous, but thinking about a project and actually constructing it are two different things. So then, can a mobile station be built, configured, and operated to produce reliable water quality data? Can it be built for a reasonable price? Answering these question are the impetus for this report. What follows is an analysis of station planning considerations, analysis of each of the component systems required to build and operate a mobile station, and a cost comparison of various station configurations. These will be assessed to determine if a station can be built, and done so in a cost effective manner. Aside from determining if the mobile station concept has merit, this report is intended to be used as a planning guide for those interested in building a similar station.

3. Methodology

For the purposes of this proof of concept, a successful mobile station will be capable of producing the same parameters, frequency, and quality of data as produced by the permanent stations currently in operation. Also considered will be system design and development, including construction costs and mobile station specific system constraints.

Although seemingly straight forward, ensuring that the proper station components are selected is more complicated than with a traditional station. This is because permanent stations can be designed inefficiently, because the power supply is not limiting. But in the mobile station concept, power consumption dictates that all systems be as efficient as possible. Because components are selected based on efficiency, other systems are more likely to be impacted. For this reason there is a balance that must be maintained between station mobility and capability that is dictated by weight, transport, power supply and production, along with safety and security. The schematic below (Figure 2) outlines all of the component systems, and gives some sense of the *feedback loop* nature of developing such a complicated system.

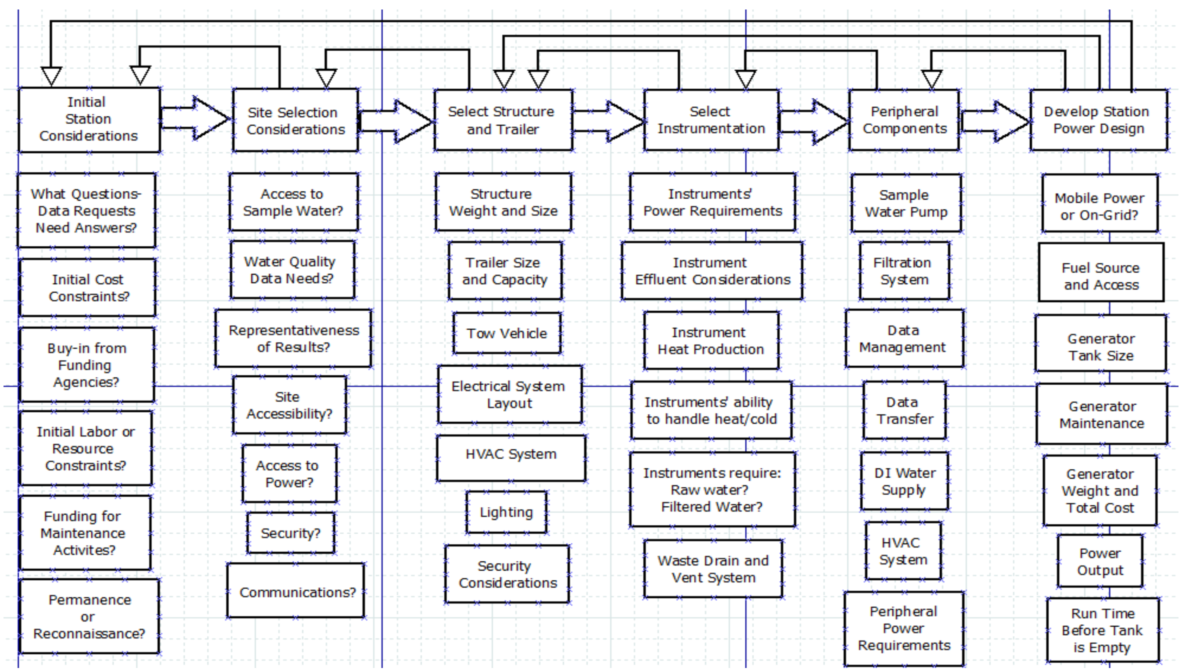

Figure 2. Water Quality Mobile Station Planning Matrix

3.1 Test/Design Process

To accurately assess the feasibility of the mobile station concept, all of the above planning matrix components will be addressed. In order to give some framework to the forthcoming discussion, the following section will define the methodology used for assessing each component system.

Planning Considerations/Intended Application

For the purpose of this report, the intended application is a full-time water quality monitoring station with the versatility to be staged at almost any location. Since the application could be drastically different given the intended use, it is important to fully assess the station's intended use prior to preceding to further steps in station development. The *Planning Considerations/Intended Application* section will cover this and other topics such as station locating, and station cost and effort.

Mobility/Foundation

Mobility refers to the method of transporting the mobile station to its intended location. In most cases, transport could be a Class C truck assigned to a DWR unit. Depending on the size of the shelter, it could be a Class A or B DWR truck and trailer, or a rental truck and driver from a transport company. Foundation refers to how the station will maintain its position at that location. For instance, if the temporary placement is on a levee toe, the foundation would likely be a trailer. If the station was intended to be installed on a lake, the foundation would likely be a small floating barge on which the station could be placed. Aside from assessing the different options available, cost of such components will also be evaluated. The mobility and foundation topics are combined because they are closely linked and could be the one in the same.

Shelter

Shelter is defined as all of the components included with the structure. The discussion will include selecting the correctly-sized station systems include the heating, ventilation, and air conditioning (HVAC) system, interior lighting, and electrical panel and outlets. Along with these, the power system and trailer may be included if the vendor is able to supply each at a cost benefit. In the report, various mobile station designs will be assessed as well as a cost analysis of each. Full cost analysis is presented in chapter 5.

Power

Power is defined as the electrical system selected to provide power to operate the stations electrical components. Various methods of powering a station are assessed as well as the availability and associated cost of each. Aside from power supply, power demand of component systems is also addressed. Instrumentation refers to the water quality measuring equipment installed in the mobile station or shelter.

Instrumentation

The list of possible instrumentation is unending, therefore the focus in this report is on the current constituents of interest, with some additional discussion on selected instrumentation that might be of interest in the mobile station application. Covered under the instrumentation section is the expected instrumentation cost, power consumption, instrument footprint, and instrument environmental requirements.

Other Peripheral Systems

In terms of this report, *peripheral systems* refers to any additional components required to operate the station not already built into the shelter by the station vendor or covered in other sections. A lot of components fall into this category including sample water pump and delivery system, clean water connections and drain, and data management and data transfer systems. These systems are an important consideration, but for the most part are similar in design to those already installed in permanent structures.

Security

Security features are an important part of any remotely located station, as theft and vandalism are ever-present. In this report, *security* refers to any systems or features that can be added to the station to further minimize the likelihood of theft or vandalism. Security is a part of permanent structures so the focus here will be on mobile station specific security measures.

Total Cost

Cost in this report is a measurement of many things including the equipment and labor charges required to bring a mobile station online. To assess the cost of a mobile station, multiple vendors were asked for itemized quotes. Instrumentation and peripheral systems required to bring the station online will also be assessed as part of cost. This information is needed to assess the actual cost of a mobile station, which can then be compared against the cost of installing a permanent station.

3.2. Report Resources

Various sources were consulted during the production of this report. Below are the examined resources, arranged by station component.

Mobility/Foundation:

- **DWR's Flood Management Division**, 1450 Riverbank Road, West Sacramento, CA 95605
  Phil Carey, (916)375-4004. Foundation: concrete and construction
  Mike Salvador, (916)375-6000. Mobility: truck and trailer transport, equipment rental
- **Load Trail**, 220 F.M 2216, Sumner, TX 75486. Sales Department, wholesale only, (903) 783-3900
- **Featherlite Trailers**, Hwy 63 & 9, P.O. Box 320, Cresco, IA 52136. (800) 800-1230
- **Travln Toys**, 21200 South Paradise Road, Tracy, CA 95304. Dave, (209) 833-9111
- **DWR's Office of Fleet Management**, O&M Fleet Mgmt., Mobile Equipment Office, Bakersfield, CA 93313. Brian Borlace, (661) 333-0625
- **Hoblit Chrysler Jeep Dodge**, 333 Main Street, Woodland, CA 95695. Grady in Fleet Sales, (888) 255-1741
- **Woodland Motors**, 1680 East Main Street, Woodland, CA 95776. Matt, (800) 896-0199
- **Elm Ford**, 346 Main Street, Woodland, CA 95695. Rigo Torres, (800) 266-2817

Shelter or Mobile Station:

- **Shelter One**, 5887 Monument Drive, Grants Pass, OR 97526. Norm Yoder, (541) 479-4622
- **Sun West Engineering**, 3802 E Broadway Road, Phoenix, AZ 85040. Phil McCoy, (602) 275-0662
- **EKTO**, P.O. Box 449 Eagle Drive, Sanford, Maine 04073. Willy A. Faessler, (207) 324-4427
- **Precision Quincy**, 4600 N. Mason-Montgomery Road, Mason, Ohio 45040. Jeff Carson, (513) 923-5940
- **Western Shelter Systems**, 830 Wilson Street, Eugene, OR 97402. Anthony Petrone, (541) 344-7267
- **SunDowner Trailers**, 505 Hilltop Drive, Auburn, CA 95603. Eric Rojas, (530) 887-9502
- **SeaBox**, 1 Sea Box Drive, East Riverton, NJ 08077-2004. Bob Welsch, (856) 303-1101, Ext. 4231
- **Container Solutions Inc.**, 2449 Bates Ave., Concord, CA 94520. Phil Herndon, (800) 506-7368
- **CA Air Resources Board**, Monitoring and Laboratory Division, 1927 13th Street, Sacramento, CA 95811 Mac McDougall, (916) 327-4720. Mac was contacted because CARB owns and uses shelters from EKTO, Shelter One, and Wells Cargo (sold by SunDowner) for CEMS (Continuous Emissions Monitoring System).

Power:

- **Pacific Gas & Electric**, 5555 Florin-Perkins Road, Sacramento, CA 95826. (800) 684-4648

Building and Renovations, (877) 743-7782; Sacramento Service Planning, Engineering, (916) 386-5112; PG&E's Greenbook online application for service provision.

- **Sierra Pacific Fleet Service**, 971 F Street, West Sacramento, CA 95605
  Russ Guilliam, (916)373-0650
- **Power Generation Sales/Cummins West**, 875 Riverside Parkway, West Sacramento, CA 95605.
  Bob Robbins, (916) 376-1533
- **Suburban Propane**, 23901 S Chrisman Road, Tracy, CA 95304-8022. (209) 835-2115.
  Mike in Account Services, (209) 321-0318.
- **United Rentals**, 4125 Breakwater Ave., Hayward, CA 94545. James Burr, (510) 670-0373.
- **Sunbelt Rentals**, 3751 Commerce Drive, West Sacramento, CA 95691. (916)371-2555.

Instrumentation:

- **Thermo Fisher/Dionex Corporation**, 1228 Titan way, Sunnyvale, CA 94088.
  Christine Wieser-Punty, Senior Field Service Representative, Unity Lab Services, (925) 890-5084.
- **GE Analytical Instruments/Sievers**, 6060 Spine Road, Boulder, CO 80301.
  Carl Campbell, Technical Support Specialist, Test & Calibration Technician, (888)245-2595
- **YSI Incorporated**, 1700/1725 Brannum Lane, Yellow Springs, Ohio 45387.
  David Lee, Monitoring Sondes, California Distributor, (916)421-5199
- **SonTek**, 9940 Summers Ridge Road, San Diego, CA 92121-3091. Joel, main phone, (858) 546-8327
- Ron Nauman, HydroScientific West, 12528 Kirkham Court, Poway, CA 92064. (858) 486-8825
- **DWR's Division of Integrated Regional Water Management**, North Central Region Office, 3500 Industrial Blvd., West Sacramento, CA 95605; Dave Huston, Flow Monitoring & Special Studies Supervisor, (916) 376-9654.
- **DWR's Operations and Maintenance SWP Operations Support Branch**, Environmental Assessment Branch, Special Projects Section, 1416 9th Street, Sacramento, CA 95814, Room 620.
  Tanya Veldhuizen, Aquatic Nuisance Species Program, (916) 657-3609.
- **DWR's Division of State Integrated Water Management**, Land and Water Use, Water Use
  Cayle Little, (916) 654-6265.

Other Peripheral Systems:

- **Ryan Herco Flow Solutions**, 8500 Morrision Creek Road, Sacramento, CA 95828. Main, (916) 381-1141; Mike Traywick, Senior Technical Sales Representative, Burbank, CA.
- **Harrington Industrial Plastics**, 5071 Kelton Way Suite 400, Sacramento, CA 95838.
  Ray Eagles, Technical Sales, (916) 920-5392.
- **Netafim USA**, 5470 East Home Ave. Fresno, CA 93727. Jim McCarty, Tech Support, (888) 638-2346.

Security:

- **Gerlinger Steel & Supply, Inc.**, 1510 Tanforan Ave. Woodland, CA 95776. Rick Eagle, (530) 406-0492
- **MSC Industrial Direct Co.**, 2300 East Newlands Drive, Fernley, NV 89408; Travis Welch, Sales Rep, (916) 792-1751. Kathleen Francis, (775) 788-7300, Government Contract Service Division
- **Newegg**, 9997 Rose Hills Road, Whittier, CA 90601. Main phone, (800) 390-1119 www.newegg.com
- **DWR's Public Affairs Office**, Media & Public Information Branch, 1416 9th Street, Sacramento, CA 95814, Rm 204-21. Maggie Macias, (916) 653-8743
- **DWR's Facilities & Property Branch**, 1416 9th Street, Sacramento, CA 95814, Room 338.

Kris Heller, (916) 653-7233

- **DWR's Division of Engineering**, Real Estate Branch, SWP Acquisitions, 1416 9th Street, Sacramento, CA 95814. Linus Paulus, Senior Right of Way Agent, Room 425, (916) 653-3947

Maintenance:

- **DWR's O&M Fleet Management**, Sacramento Shop, 1450 Riverbank Road, West Sacramento, CA 95605. Matt Samson, Heavy Equipment Mechanic, (916) 376-1973

Labor:

- **DWR's Division of Flood Management**, Sacramento Maintenance Yard, 1450 Riverbank Road, West Sacramento, CA 95605. Russ Eckman, Utility Craftworker Superintendent, (916) 375-6004
- **DWR's O&M Fleet Management**, Sacramento Shop, 1450 Riverbank Road, West Sacramento, CA 95605. Robert Neves, Senior Auto Equipment Inspector, (916)216-8372

4. Station Component Analysis

4.1 Planning Considerations

Constructing a station of this complexity requires cautious planning, conservative estimations, and broad initial research to ensure the components will function together as a reliable unit, and also produce the appropriate data. The following sections provide greater detail regarding such planning considerations.

Intended Application

The initial step in any project is to clearly define the purpose and goals. Mobile station planning is no different. What analytes are needed? What frequency data are required? Are existing data available that can answer the questions? If not, are there existing data that could be used to develop regressions for the needed data? How long will data need to be provided at this site? Before seriously beginning the mobile station planning process these questions need to be answered. The cost of installing a station can be high, so ensuring that the station is *actually needed* should be priority one. Imagine spending time and money building a mobile station, only to find the needed data already available online after a 10 minute internet search.

Once the need for a mobile station is confirmed, station planning and design can commence. Have a good sense of what type of data are needed, as this will guide the scaling of the mobile station. Although it is cheaper to size the station to the current requirements, it is often prudent to consider future data needs. That is, if the cost of making the station a little bigger and more capable is feasible, then doing so will decrease costs if future instrumentation needs to be added. Another thing to consider is that even if the station is intended to be temporary, it is best to go through the planning process as if the station will be permanent. Ask questions such as--Can the mobile station be converted to a permanent station? Is there power available for conversion to permanency? Is the landowner open to the possibility of a permanent structure? Having pre-planned, converting to permanence will not result in the need to restarted installation from scratch.

Location

Locating a mobile station, as with all sampling sites, is not solely based on what location provides the best data, but requires broader considerations. One must achieve a balance between current data needs, historical data collections, convenience or cost, and the security level of the site. It is assumed that the correct water body has been selected, but picking the right location on-site is also important. For instance, picking a location directly downstream of a point source may not be the best idea. Also, the station's proximity to the waterway must be a factor, as water delivery pumps have their limits. For instance, the maximum head of most "pulling" style pumps is 25 vertical feet. For longer runs, a submersible pump does not have this limit, but requires that the electrical connection be made at the pump instead of inside the shelter. While easy to install, the pump and electrical connection would be exposed to theft.

Also consider access constraints to the site. There are many locations in the Delta that make sense from a data quality standpoint, but are effectively inaccessible due to landowners' unwillingness to provide legal passage. Even if a landowner is open to allowing access, processes such as attaining Temporary Entry Permits (TEP's) may result in additional time and cost.

Security is covered elsewhere in this document, but during the site selection phase the likelihood of vandalism should be assessed. That is, if the mobile station can be moved downstream 1000 feet to be near a lighted and visible location, it might be wise to do so.

Aside from gaining access to the site, it is also important to consider the time and safety of staff who will be accessing the site. Having to drive a mile down a dirt-capped levee road is fine during the dry season, but might be hazardous during the wet season. Also, locating the station on the outside bend of a highway may not be the wisest positioning from the stand point of safety.

Another consideration is the stability of the selected site. Does this location flood once every five years? Is a major construction project slated to begin next month or next year adjacent to the site? Is the site near an eroding stream bank? The possibilities are vast, so researching the history and future of the site is an important part of site section.

Lastly, the selected site needs to be assessed to determine if it has any ecologically sensitive characteristics. Specialized staff within DWR should be used as a resource for such determinations.

There is a lot to consider when locating a monitoring site. Most likely, the best site for one consideration will not be the best for another. During the site selection process, the goal shouldn't be perfection, just what is pragmatic and workable.

Cost and Effort

During the planning phase it is important to fully assess how much time and money the organization is willing to spend to build a mobile station. In many instances, those requesting data are unaware of the true cost to collect continuous data at a new location. Being prepared to inform data requestors of the cost can act as a rude awakening, and may result in the thoughtful reevaluation of the data need.

The total cost of a completed real-time station is comprised of the initial research and planning, equipment received from vendors, the wages of staff used to finish the station and make it operational, and also the annual operating costs. One benefit of the mobile station concept is that if the station is not in use, it is not incurring cost whereas a permanent station has continuous maintenance related costs even if it is not operational. In Section 5, the cost of a mobile monitoring stations is estimated which is intended to be useful when in budget discussions.

4.2. Foundation/Mobility

Station foundation and mobility refers to the components which the station sits upon and how the station is moved from one site to another. In the case of a mobile station, the foundation will most likely be some sort of trailer, either a separate trailer on which the station shelter sits, or possibly a cargo type trailer where the shelter and trailer are integrated. If the selected configuration contains a separate trailer, it is expected that during a temporary installation the station/shelter would stay on the trailer. The type of foundation selected will impact how the station is transported from one location to another. In this case, the vehicle used to move the station would need to be properly sized based on the size and weight of the station/trailer.

As stated previously, all of these components are interconnected, but for the sake of simplicity the following sections will address the trailer and vehicle options independently.

Trailer

When selecting a trailer, consideration should be given to the weight and size of the shelter, generator, fuel tank, battery bank, and other equipment. Aside from weight limitations, special consideration must be given to weight distribution. With the shelter on the deck, a tail-heavy trailer can fish-tail on flat ground or be unruly on a decline. If the trailer is too heavy on the tongue, exceeding the truck's rated weight capacity, problems may occur with the vehicle's rear suspension and steering. Therefore, on a case by case basis, the weight and position of each component needs to be determined before selecting the trailer. Given the right conditions, an off-the-shelf trailer may work, but special care will need to be given to ensure it meets the specifications. Retrofitting or altering a standard trailer may compromise its pre-engineered integrity, reduce safety, and possibly increase the final price above what a custom trailer (Figure 3) might cost without performing as well.

Figure 3. Custom cargo trailer monitoring station

Shelter Deployment Options

Once the mobile station is on site, deployment options exist depending on what type of configuration has been selected. Below are a few possibilities for temporarily deploying the mobile station.

Permanently attached to trailer, integrated framing, or cargo trailer: For a shelter built upon a trailer frame and axles, the preferred method of keeping it stationary for an extended period is to keep the tires off of the ground. Jacking up the trailer, setting it on jack stands, removing the wheels and tires, and using a devices that locks out the hubs and lugs will provide stability and security for this type of

Figure 4. Flat-bed trailer with removable shelter

shelter. Keeping the tires off of the ground will prevent them from developing permanent flat spots that will affect performance under tow.

Self-deployable shelter--Slide mounts and lifting jacks attached to shelter: This type of lift system has been proposed by Shelter One and EKTO Manufacturing for lifting a small shelter off of its trailer so that the trailer can be pulled out from under the shelter, and the shelter lowered to the ground. The shelter can be placed back onto the trailer by simply reversing the process. With this lift system, the shelter can remain on the lifting jacks for as long as desired, or set onto the ground and the jacks removed from the shelter, in order to prevent theft. Shelters designed to use lifting jacks have a base skid with a metal track or locking pin for attachment to the transport trailer. This skid can also be used to rest the shelter on the ground, either with simple blocks for leveling, or set directly on a purpose built concrete pad to which the shelter can be permanently anchored.

Separate trailer and a lightweight shelter (<5000lbs.): For a shelter weighing under 5,000 pounds (Figure 4) and within the spatial requirements of the rigging and deck (8' x 16'), the SMY boom truck can be hired for the cost of the driver, $105/hr. The boom truck can park parallel to the shelter and trailer, lift the shelter off of the trailer by its lift eyes (D-rings), and set on site. A smaller shelter can be carried on the deck of the boom truck, while a larger one can be carried on an accompanying trailer.

Separate trailer and a heavier shelter (>5000lbs.): For a shelter weighing over 5,000 pounds, or one that is simply too large to be handled by the SMY boom truck, a mobile crane can be hired for a number of hours to lift and set the shelter. A shelter can be carried to the site, either by its own purpose built trailer or one belonging to the SMY, of which there are many sizes and weight capacities. A mobile crane can meet on site with the necessary lifting equipment (spreader bar, slings, etc.) and lift the shelter from the trailer to the slab or prepared substrate. Because this would be a one-time service call, and not a service contract, the crane charges can be paid for using a Cal-Card VISA.

Mobility

Mobile stations need to be transported from one site to the next, so using some sort of hauling or towing vehicle makes the most sense. Options for station transport will generally be limited to vehicles within the state fleet, unless a one-time purchase can be made for transport services. That said, the Sacramento Maintenance Yard has enough equipment and drivers to transport many of the shelters and trailers proposed in this report.

The weight of the mobile station is limited by the towing capacity of the vehicle used to pull it. Every truck has a designated *gross combined weight rating (GCWR)* that indicates the maximum weight for the truck, cargo, and trailer combined. Trucks also have a *gross vehicle weight rating (GVWR)* that provides a safe limit to the total weight of the equipment, cargo, passengers, and the truck itself. The GVWR must include the tongue weight of the trailer as part of the calculation when determining the most suitable vehicle for towing.

The total weight of the mobile station will determine which truck configuration should be used, so here are some options:

1. If the mobile station weighs 12,500 lbs. or less, the MWQI Ford F-350 will be a suitable tow vehicle if equipped with a weight-distributing hitch.

2. If the mobile station weighs between 12,500 and 15,000 lbs., the service body can be removed from the MWQI Ford to save weight and a goose-neck hitch added to accommodate the extra trailer tongue weight. If the mobile station weighs more than 15,000 lbs., no MWQI vehicle would be able to tow it.

3. Borrow a truck from the Sacramento Maintenance Yard (SMY) located at the Bryte Yard. The SMY has a Ford F-450 flat-bed dually truck that is capable of pulling 16,000 lbs. conventionally or 18,300 lbs. using a goose-neck hitch. MWQI would have to buy the folding goose-neck hitch (~$500), but the truck can be made available at no charge.

For any of these options, if MWQI wanted to hire a utility craftsworker to drive the truck, the rate is $105/hour or $945/day, with DWR equipment rental and fuel included. (4/11/2014 conversation with SMY supervisor Russ Eckman). Hiring a utility craftsworker as a driver is the safest option as most are trained to operate larger trucks and possess Class A or B licenses.

4.3. Shelter

The shelter is the station structure in which the instrumentation is housed. The shelter either sits upon the foundation (for example, flatbed trailer) or is an integrated part of the trailer (cargo trailer). Although the basic shelter design is pretty straightforward, each manufacturer has their own take on shelter construction. In this section, the various designs employed by the vendors and construction units are addressed and the designs compared using a standardized set of dimensions for the shelter.

Generally speaking the mobile station needs to conform to minimum requirements. These requirements might change some, but these basic design cues should be in every shelter:

- Have walls that are strong enough to support equipment
- Be sealed and insulated sufficiently to keep out moisture and limit temperature swings
- Be securable, and limit opportunities for vandalism and theft
- Have big enough interior dimensions to fit all needed instruments
- Have lighting and electrical outlets
- Likely have temperature control equipment. If instrumentation does not have temperature requirements, then ventilation may be sufficient
- Access point appropriately sized for largest piece of equipment
- Small enough to be moved via truck and trailer (highway permissible)

There are many variations in shelter designs available, so to simplify the comparison, the trailer styles and associated pros and cons are described in Table 1.

Table 1. Shelter designs categories and associated pros and cons.

Shelter Type	Pros	Cons
Lightweight Cargo Trailer: Typical enclosed trailer or 'toy hauler'	• Easily available in a variety of sizes and configurations. • Easy to tow and maintain. • Low cost compared to other options. • Can be ordered with a small generator, electrical system, and HVAC on board.	• Low level of security: Thin-wall metal and siding, easy to cut through. • Commonly carries equipment, making it more attractive to thieves.
Integrated with Trailer: Structure is built into/onto the trailer's frame.	• Lighter weight by using less heavy framing or base skid. • More maneuverable: lower overall height, lower center of gravity. • Safer to tow, potential for using a lighter truck. • Uses less metal and less frame work.	• Single purpose shelter that cannot be removed from the trailer.
Narrow Shelter on a Car Trailer: Shelter fits between fenders, at 6' 9" wide.	• Shelter is deployable and can be separated without extra equipment. • Narrow width makes it easier to transport on levee roads with trees. • Shelter sitting lower than trailer tires keeps center of gravity low. • Better visibility and lower wind resistance, making it easier to tow. • Some weight and costs savings of a smaller shelter and trailer.	• Smaller shelter, less square footage for equipment. • Narrow width dictates a *galley* style arrangement of equipment. • More weight added with frame of trailer and base frame of shelter. • More cost: slide mounts on trailer and shelter, plus lifting jacks.
Full width Shelter on a Flat Deck Trailer: 8' 6", no signage needed.	• Maximize the width, therefore the overall size of the shelter. • Still deployable without any extra vehicles or equipment. • More open floor plan allows for better ergonomics.	• Larger, heavier trailer and shelter can be more difficult to tow. • Less visibility and higher center of gravity and overall height. • Added cost associated with larger shelter and trailer. • Added costs of slide mounts and lifting jacks.
Any-size Shelter, under 8' 6" wide, separate Trailer: Purchase a trailer.	• Buy a quality trailer of a universal design to transport MWQI projects. • Costs savings by buying a non-specialized, typical trailer.	• Purchasing time and some maintenance required for trailer. • Will have to hire a crane to unload the shelter. • Equipment weight will have to be calculated and balanced by DWR personnel.
Any-size Shelter, under 8' 6" wide, using DWR Trailer: Borrow a trailer.	• Use a trailer belonging to Sacramento Maintenance Yard. • Road-legal shelter, avoid the cost of trailer and maintenance. • Hire SMY driver; includes the cost of towing equipment and fuel. • Don't have to modify MWQI vehicles.	• Would be subject to another Division's schedule. • Could not keep the shelter on the trailer for more than a few days. • Will have to hire a crane to unload the shelter. • Equipment weight will have to be calculated and balanced by DWR personnel.
Using an ISO Cargo Container for a Station Shelter:	• Already constructed, just needs retrofitting and upgrades. • Road-ready size with inherent transport features. • High level of security, with aftermarket doors available. • Inconspicuous appearance; common use. • Available in a refrigerated models that have extra insulation and stainless steel interiors.	• Heavy, making transport more difficult and requiring third party crane service. • Dimensions are typically set: 8' width with lengths in 10' increments (8x10', 8x20'), and though possible, altered sizes add to the cost. • Can be more expensive per sq. ft., depending on vendor. • Can be viewed as having valuable tools/equipment inside, increasing the risk of a security breach.

When attempting to assess the weight of shelters, it is difficult to compare one type to another. To help make an *apples to apples* comparison, some of the proposed shelter types have been converted to an 8' x 8' x 8' standard size. Doing so, the expected weights are as follows:

- An ISO container weighs approximately 2,500 pounds, with no interior paneling.
- A refrigerated ISO weighs approximately 3,300 pounds, maybe less without the A/C unit.
- Fabricated Metals brand shelter (the same used by O&M on the SBA) is about 2,500 pounds with the insulation and interior paneling.
- EKTO brand shelters are rated at 150 lb/ft., making it 1200 pounds empty.
- Precision Quincy brand shelter is estimated at 1500 pounds empty.

To put it in perspective, the Shelter One building purchased for the Gianelli real-time station is made of a steel skid and framing, with fiber-cement exterior paneling and OSB/FRP interior paneling, extra insulation, and a side-mounted HVAC unit. This shelter is 14' x 8' x 8', making it 112 square feet and weighing 5,800 pounds. For a truly mobile application the Gianelli building could have been designed to save additional weight.

Depending on the intended use, a lot of weight can be saved by selecting lighter materials. Weight savings might come at the expense of rigidity and security depending on the application. Therefore, careful consideration should be given when selecting a shelter type.

Although not clearly required, it is preferable that the shelter be built to California's building and energy codes so as not to restrict the station's potential locations or risk being out of compliance as a permanent structure. Even if not required, the structure should meet permit requirements for seismic, wind, and snow loads. Also of note, ISO or shipping containers are allowed to be used for equipment storage, but not for any occupancy or inclusion of plumbing from city/county utilities. (Yolo County Code Relating to Accessory Structures, Sect.2, Title 8, Chapter 2.3404.)

4.4. Power

Electrical power is easy to overlook during station planning because power is almost always available. But in the mobile station application, where stations are often away from existing infrastructure, it becomes an integral part of the planning and design. Supplying enough power to operate the mobile station is imperative, but oversizing the power system can add expense, waste fuel, and be limiting to other station components. Also, the more complex a system is, the more maintenance will be required, so simplicity should be the goal. The simplest option, and the one that should be strived for during planning, is to have low power demand equipment so that the station can function solely on battery/solar power. If power demands are too high, the next best option is to make a temporary electrical connection to the grid. Beyond that, things get more complicated. This section looks at requirements for power system planning and also at some of the power options available for a mobile station.

Estimating Power Demands

Regardless of what power system is selected, the first step is to determine how much power the station will require to operate. The less power used by the station, the cheaper and easier it will be to build and operate. By this point, the water quality data requirements should be known. If an expensive/lower power use instrument produces the same data as a cheaper/higher power use instrument, it might be prudent to select the low power instrument. There is a huge range of electrical demands for station components, so Table 2 has estimated power requirements for the systems most likely to be used in a mobile station. Using equipment that is electrically efficient can drastically decrease the size of the electrical system needed.

Table 2. Estimated Power Requirements* of Station Equipment

Station Component	Description	Purpose	Power Required (watts)		Run Time (% of time)
			Peak	Typical	
Shelter Related	Small HVAC, heat and cool, portable	Temperature Control of the Shelter	1360	--	5%
	Small HVAC, cool only, window style	Temperature Control of the Shelter	475	--	5%
	Lights: Interior	Visibility	--	50	<1%
	Lights: Exterior	Security	--	20	50%
Security	Motion-Lights	Warn Visitors			<1%
	Motion-Cameras	Record Faces			<1%
	Alarm: Audible & Flashing Red	Deter Thieves, Alert Others			<1%
Analytical	Dionex ICS2100	Analyze Anions	--	85	100%
	Metrohm	Analyze Anions	--	60	100%
	Sievers 5310 C	Analyze Carbon	--	50	100%
	YSI 6600 or EXO sonde with probes	Physical Water Quality Parameters	1.2	0.1	100%
	Turner Cyclops 7, FDOM probe	Optical Detection of Organics	--	0.3	100%
	SonTek SL "side-looking" Doppler	Measures water flow in channel	4	2	50%
	Weather Station	Measure Atmos. Conditions	--	<20	100%
Instrument Control and Communication	Computer	Run software for the anion analyzer, log data, control valves	105	60	100%
	Computer monitor	visualization	95	90	<1%
	Campbell Scientific Data Logger	Log Data from Weather station	0.3	0.2	100%
	Cellular modem	Transfer Data	5	3	100%
Mechanical	Intake Pump, Gianelli	Provide Water	--	800	100%
	Intake Pump, small	Provide Water	108	--	100%
	Valve System	Shunt Water	10	10	50%
	DI Pump	Provide DI Water	70	70	<1%

*wattage data collected from multiple sources including manufacturer information and through load assessment data collected from APC Smart-UPS 750 battery back-ups.

Table 3. Estimated power requirements for *current suite* mobile station.

System	Instantaneous Peak Demand (watts)	Run-time multiplier	Run-time compensated average demand (watts)
HVAC (portable)	1360	0.05	68
Interior lights	50	0.01	0.5
Exterior motion lights	20	0.01	0.2
Sievers TOC analyzer	50	1	50
Dionex IC analyzer	50	1	50
Dionex sample prep	50	1	50
YSI Sonde	0.5	1	0.5
Computer	60	1	60
Computer monitor	90	0.01	0.9
Datalogger	0.2	1	0.2
sample delivery pump (Gianelli)	750	1	750
Water system valves	10	0.5	5
DI pump	70	0.01	0.7
	Station total of average demand		1036
	Station total peak expected demand		1554
	Station total maximum possible demand		2561

Electrical power supply is split into two categories: on-grid, as supplied by a local utility company; and off-grid, which is independent of remotely metered service and usually supplied and maintained by the owner. As stated earlier, there are many options available to power the station, some cheaper and easier than others. The following sections will look at these on-grid and off-grid power options.

Reality Check:
The Gianelli Real-Time station has a 100 amp panel, supplied from the power plant's switchyard, but the station itself only requires about 50 amps for full operation at peak consumption.

On-Grid

If the proposed site is near a service provider, then setting up a utility connection may be the most pragmatic solution. Typically, a temporary electrical service of 200 amps or less can be connected for about $1200. For connections over a one-year term, Federal and State taxes must be collected. For a permanent connection, the price range varies from $1000 to over $10,000, depending upon the additional work needed to establish the connection, such as infrastructure upgrades, required easements, and distance from the source. PG&E states that approximately 75% of projects cost under $5000, but the building must be properly set-up by the owner to accept the electrical or natural gas connection. Schematics for the various connection options are detailed in PG&E's Greenbook of electrical and gas service requirements. (www.pge.com/customerservice/newconstruction)

Although an unlikely scenario, the selected location may have natural gas service available, but not electrical service. In such a case, a natural gas burning generator can provide electricity to the station for the monthly rate of natural gas. That said, natural gas generators have certain limitations and advantages. More information about the natural gas generator can be found in the *Off-Grid* section, below.

Off Grid, Low Power Demand

Batteries only is likely the easiest way to power a remote station. If power demand is low enough, batteries can be swapped out on site visits which will negate the need for on-site charging systems (such as a solar or generator system).

The batteries themselves should be housed in their own air-conditioned strong box in order to keep them cool and efficient. Depending on the power demand, batteries should be of a high amp/hour variety so that when placed in series, the amperage adds up to enough power for the station. The voltage sum should be 12, 24, or ideally 48 volts to work with any needed power inverter. The 48 volt system is preferable because less current is drawn and less heat produced during the current transformation process.

Figure 5. Preassembled Magnum Energy 4,400 Watt Inverter Kit with Classic 200 Charge Controller. Estimated cost $4225.

The number of batteries required will be dependent upon the current demand of the equipment. Batteries have a maximum discharge/charge rate that needs to be figured when calculating the number and size of batteries. The rate is specific to the type of battery. A *flooded lead acid* (FLA) deep cycle battery has an acceptable charge/discharge rate of about 1/8 of the batteries amp hour rating, whereas a sealed lead acid (SLA) battery can discharge at 1/4 of the amp hour rating. For example, a 105Ah FLA battery's draw or discharge should not exceed 13 amps to maximize system operation and battery life.

In reality, any battery system that requires an inverter will likely have high enough power draw to require an on-site battery charging system.

Power and Charging Systems

Designing an off-grid power sytem that includes a properly designed and sized battery, inverter, and charging system is not a task for the layperson, and therefore design and installation should be carried out by a trained electrician. Figure 6 is a schematic of a multi source powering system that could be used to power a mobile station. Depending on the power demand, the complexity of the charging system is affected. For instance, a lower power demand off-grid system might not require the generator assist power designed into Figure 6.

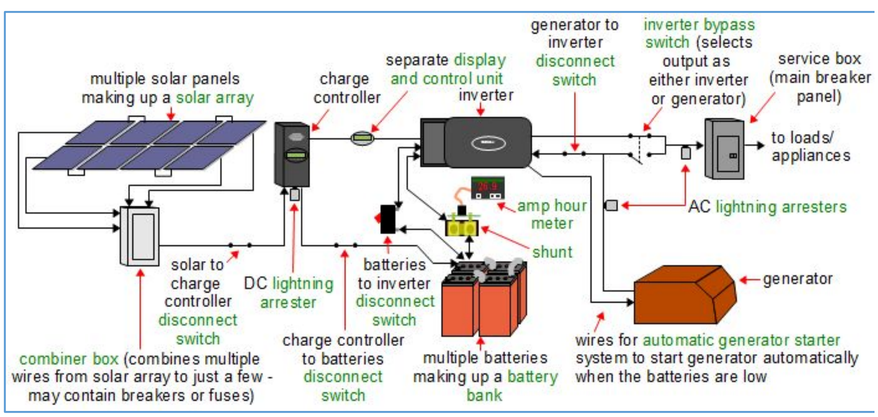

Figure 6. Common configuration of multi-source off-grid power supply

Off the shelf power systems that are appropriate for use in the mobile station concept are available. Using the station power demand figured in Table 3, a system such as the *BPS 4400 Watt Back Up Power System* (Figure 7) could be installed in the mobile station by a trainied electricial at a cost of around $8000 (parts only). This cost includeds all of the controllers and other components needed to connect to solar or generator charging systems. This system is oversized for the expected station power demand, so it might be possible to downsize the power system and thereby save on system cost, size, and weight.

Figure 7. *All in one* BPS 4400 Watt Back Up Power System (Model# BPS4448M) which can be configured for off-grid applications. Approx. $8000 (source: Northern Tool & Equipment)

Renewable Technologies

There may be some value in investigating the following forms of renewable energy, but the equipment required does not lend itself very well to the mobile concept--with a solar array being the exception for low demand systems. Setting up a hydro-generator or wind turbine is a project better suited for a permanent station installation. The following section has some basic information regarding the use of these renewable energy sources.

Solar

Photovoltaics are an accepted method of providing power, but there are some limiting factors that may come into play when designing a mobile station system.

Incorporating solar panels into a mobile station is not too complicated as panels can be attached directly to the shelter. Panels placed on the roof and sides of a shelter, with hinges on the eaves, allow the user to angle or pitch the panels to optimize the orientation to the sun. Under transport, the side panels can be folded and secured against the shelter walls, while the roof panels are set down flat. The panels would only increase the overall width of the shelter by a few inches per side, and the overall height by a few inches. The overall surface area available on the shelter dictates the size and power that can be yielded from solar panels. Common shelters sizes can provide a rough estimate of the surface area available (Table 4).

Table 4. Shelter size and corresponding surface area for solar panel installation.

Size: L x W x H	Area of One Side	Area of Other Side	Area of Roof	Total Surface Area
8 x 8 x 8 ft.	64'	64'	64'	192'
6 x 10 x 8 ft.	60'	80'	80'	220'
6 x 8 x 8 ft.	48'	64'	64'	174'
8 x 10 x 8 ft.	80'	80'	80'	240'
Average Areas	63'	72'	72'	~206'

With some of the surface area taken for hinge attachment and latches, the average available surface area for solar panels is **200 square feet** (sq. ft.) based on the expected size of a mobile station. The size and weight of panels used should be considered and are estimated in Table 5.

Table 5. Size and weight of typical solar panels. Provided by http://brightstarsolar.net.

Type	Length	Width	Thickness	Weight	Area	# of cells
Residential	65"	39"	1.4"	40 lbs.	17.6 sq. ft.	60
Commercial	77"	39"	1.8"	50 lbs.	20.9 sq. ft.	72

To utilize the available average surface area of 200 sq. ft., 12 residential panels totaling 211.2 sq ft., or 10 commercial panels totaling 209 sq. ft. can be arranged on the shelter. The weight of the panels would be 480 – 500 lbs., plus the weight of the hardware used to attach and hinge the solar panels. On average, modern photovoltaic solar panels will produce 8 - 10 watts per square foot of solar panel area. For example, a roof area of 20 feet by 10 feet is 200 square-feet would produce roughly 9 watts per sq-ft, or 200 sq-ft x 9 watts/sq-ft = 1,800 watts (1.8 kW) of electric power.

The information from brightstarsolar.net and solar-estimate.org reports average power yields of 11-14 watts/sq-ft and 8-10 watts/sq-ft for solar panel, respectively. Factoring in some effects, such as power loss through the conversion of DC to AC power, panels getting dusty in the field, less than perfect orientation to the sun (no solar tracker), the average power produced by 1 sq-ft of typical solar panel can be estimated at 10 watts. So, 200 sq-ft of panels on the shelter, producing 10 watts/sq-ft for 5.5 average hours/day, could produce 11 kWh/day and 4015 kWh/year. Using the mobile station *peak maximum demand* of 2.6 kw (Table 3) as a worst case scenario, a solar system such as the one described above would only provide 18% of the start-up power and 45% of energy consumed per day.

Converting Power (watts/kW) to Energy (kWh)

One kilowatt-hour (1 kWh) means an energy source supplies 1,000 watts (1 kW) of energy for one hour. Generally, a solar energy system will provide output for about 5 hours per day. So, if you have a 1.8 kW system size and it produces for 5 hours a day, 365 days a year: This solar energy system will produce 3,285 kWh in a year (1.8 kW x 5 hours x 365 days).

If the solar panels are shaded for part of the day, the output would be reduced in accordance to the shading percentage. For example, if the panels receive 4 hours of direct sunshine a day (versus the standard 5 hours), the panels are shaded 1/5, or 20% of the time (80% of assumed direct sun shine hours received). In this case, the output of a 200 square-foot PV panel system would be 3,285 kWh per year x 80% = 2,628 kWh per year. http://solar-estimate.org

These power demand estimates, as described in Tables 2 and 3, are based on the *current suite* real-time station with the only difference being a scaled-down HVAC. The HVAC and water pump are the two highest electrical consumers in a station.

Figure 8. Examples of trailer roof mount solar paneling.

These components require 2.6 kW at initial start-up, 1.5 kW for occasional peaks during normal operation, and **1.0 kW** continuous power to keep the analyzers and peripheral devices operating. Around-the-clock operation of the station would require 24 to 30 kWh/day. The 200 sq-ft panel set described above would fall short of peak start-up by 20%, but at **11 kWh/day** could provide enough energy to operate the station for about 11 hours per day, assuming the battery system is sized sufficiently. Usable solar radiation for power production ranges throughout the year, with ~30% more energy available during the summer months when using air conditioning is essential (the stations rarely, if ever, need to be heated for the sake of the instruments). If needed, the solar panel area can be increased by about 33% by adding a fourth hinged panel set over the back of the shelter, where the access door is located. When the station is operating, the panel would swing up and away from the door, also creating an awning over the door. Weather and the winter months will provide a challenge for a solar system, making the use of a generator more necessary. Even in this winter scenario, the size, weight, cost, and fuel consumption of a generator can be greatly reduced when employing a solar array and battery system. The solar panels themselves cost ~$5000 per kW, including tax, microinverters, and hardware to mount to a standard asphalt-shingle roof. (www.grainger.com, item #31ED03, $4,493.00, Grape Solar)

For reliable operation, there are many calculations required in order to properly size and configure a solar system. The larger the power demand of the mobile station, the more complicated the solar system would need to be. Although complicated, the finished product should be more maintenance free than a fossil fuel generator so it is well worth the upfront effort if power demand is low enough.

Wind

The Sacramento-San Joaquin Delta generally receives the required average wind speed to use a small wind generator, although the majority of the State Water Project does not. So while technically feasible, the commitment level required of purchasing and erecting a wind generator is better suited to a permanently installed station within the Delta, not a mobile station or one constructed along the CA Aqueduct.

This said, if wind power is to be considered, three models popular for home use are:

SkyStream 3.7: 2.1 kW, 33-60’ tower, 12’ diameter, up to 4,800 kWh/year at 12 mph average wind. Prices range from $10,500 – $16,000, plus installation labor. (www.backyardwind.com, www.solardyne.com, www.windenergy.com)

Bergey Excel 6: 5.5 kW, 60-160’ tower, 20’ diameter, 9920 kWh/year at 11 mph average wind. Prices range from $34,000 to $57,000 depending on the tower height, without installation cost. (www.bergey.com)

Evance R9000: 5 kW, 33-60’ tower, 18’ diameter, 9170 kWh/year at 11.2 mph average wind. Prices range from $38,000-42,000+ depending on tower height, fully installed. (www.evancewind.com, www.mainerural.org)

Taller towers may be available from sources outside of the manufacturer. In the case of the SkyStream, three units are roughly equal in price and performance to the other two.

All of this performance data is from the manufacturers, and in some ways represents a best-case scenario of the wind available on site. If a wind turbine was ever considered for use at a given location, some wind speed analysis or research should be done before the investment is made. (www.windenergyfoundation.org, www.motherearthnews.com)

Hydropower

While there are small or “micro” scale hydropower machines available, they provide too little electrical power to be considered useful for a mobile station project, and most permanent installations. Hydropower machines require high head or high flow, and preferably both. Besides the unlikely physical site conditions needed to employ a hydropower machine, the outside location makes it subject to theft, easily costing $3000-5000 if lost. For a mobile station, the best use of a small hydropower machine is to recover some power and mount it to the outlet of a water quality station, using the 10-20 gpm outflow to turn the turbine at the bottom of an outlet pipe, at least 10-20 feet below the station.

Although it is a continuous 40 watts/minute, the power recovery is too insignificant to justify the initial cost. If a permanent station were to be located far away from the electrical grid, but in an area where 1000 gpm could be harnessed, then this form of renewable energy could be considered. (www.microhydropower.com)

Off Grid, High Power Demand

If the power required to operate the mobile station is high and no grid power is available, a more complex system will be needed. The high power demand scenario will likely include the already discussed battery and renewable technologies, but will also need to be supplemented with generator power. In a high power demand system, charging the batteries using photovoltaic panels alone would require a solar field much larger than the surface area of the shelter roof, and would have to be dismantled and reassembled each time the station was relocated. To get around this limitation, a generator can be used to keep the batteries charged, or at least operated to supplement the solar array.

Generators

For a station that will be kept mobile, or for one located remotely enough that grid power is unavailable, a generator is going to provide the most power for the least amount of physical space and set-up time. They come in a wide variety of sizes, configurations, and fuel sources. The generator's role should be to power the station equipment and charge the battery system, but only until the batteries are charged. To achieve this, an auto-start controller should be part of the system so that the generator can cycle based on when battery voltage is low. The generator will continue to run, charging the batteries until they reach a preset "topped-off" level. This is important for extending the service life of the engine, and also for reducing fuel costs, maintenance costs, and reducing generator emissions. There may be restrictions placed upon generator run time that would be enforced by a local or State Air Quality Management District. As far as the transition between battery and generator power, most good power inverters have a battery charger built in, so that when the generator is operating, it will charge the batteries and transfer the AC to the equipment requiring power (Figure 6).

Sizing the generator is specific to the amount of draw required by the equipment and possibly by the recommended charging level of the battery bank. Given the estimated power demands described in Table 3, and the use of a 4400 watt power system, similar to Figure 7, an appropriately sized generator would be in the 3000-4000 watt range. A generator this size would provide enough power to charge the batteries and power the station equipment with some power to spare. This size generator would be operating at a 70-90% load during operation which is an efficient range of operation for generators. Generators this size are priced in the $1000-$2000 range depending on brand and features.

The fuel used to run the generator engine will largely determine the cost of operation, maintenance, and the generator itself. The location of a station may also have a role in fuel of choice for a generator when considering how the fuel supply is delivered. The selected generator should be reliable and easily maintainable. Depending on the application one type may be preferable over another. The following section outlines the basic benefits and drawbacks of different generator types.

Natural Gas

Pros: Inexpensive fuel per gallon; plentiful; clean-burning; quiet; can run a generator at lighter loads; can be connected permanently via a grid-source/utility company and paid for monthly.

Cons: Not commonly available as a vehicle fuel source, unless the location is near a fuel station, at which point the mobile station would have to be moved to be refueled. CNG (compressed natural gas) delivery by truck is a newer technology, starting on the East Coast (bangordailynews.com). Source subject to interruption during natural disasters. Power output is lower, making price per kW higher. Initial cost for larger unit is higher. Shorter engine life expectancy compared to diesel.

Propane

Pros: Easily obtainable, transportable, and can be delivered on site with simple monthly account. Long shelf life, easy to store, clean-burning, and can operate an engine at lower load without fouling the engine's cylinders.

Cons: Somewhat expensive per gallon, more expensive to operate per kW, engine has shorter life expectancy compared to diesel, initial higher cost for the generator, complicated fuel system, pressurized tank of flammable gas.

Gasoline

Pros: Easily to obtain, more efficient than natural gas or propane.

Cons: Difficult to transport and store in large quantities, highly flammable, may not be available during power outages or disasters, somewhat expensive, less efficient that diesel.

Diesel

Pros: Common fuel source that is also available during disasters and can be purchased for less in the off-road form (red-dyed diesel), least flammable fuel source making it easier to transport, on-site delivery available, less expensive to operate per kW, competitively priced, engines perform better under high-load and over longer periods of time, high-use situations yield lower cost of operation than other fuel sources, engine life expectancy is three times higher than other water-cooled models using gaseous fuel sources, lower maintenance (less often).

Cons: May have a reduced run-time in areas with strict air quality or emissions standards, not as efficient when running light loads (<40% of output) causing engine to smoke ("wet-stacking"), double-containment tank and noise reducing enclosure system add to the cost, typically heavier than gaseous units.

Other types of Diesel: Emulsified diesel and Bio-diesel share the same advantages and disadvantages as #2 highway diesel and red off-road diesel. Each of these have become more common and can be delivered on-site. The additional advantage of each is reduced emissions, and the disadvantage is maintaining proper mixtures of each of the additives. (www.generatorjoe.net/html/genfuel.html)

4.7. Instrumentation

There are many instruments that could be installed in a mobile station, each with varying requirements, so it is important to have a good sense of what analyses will be required early in the planning process. Depending on the type of instruments installed, the required physical footprint of the station and power supply can be drastically different. The types of instrumentation that might be placed in a mobile station will be discussed in this section. Special focus will be given to the current suite of instruments that are presently installed in permanent stations as this is representative of a 'worst case scenario' as far as physical size and power demand. Of course, there are many other types of equipment that could be installed in a station, so only those most likely to be installed are discussed. Collecting basic information for these instruments, as has been done in this section, will help in assessing the viability of that instrument for use in a mobile station.

Current Suite

Power Demand: Dionex ICS2100- 120-240 VAC, 85 watts typical
Sievers 5310- 100-240 VAC, 50 watts peak, 30 watts typical
YSI 6600 Sonde- 12 VDC, 1.2 watt peak, 0.1 watt typical

Figure 9. YSI 6600 Series multi-parameter

Figure 10. Sievers 5310 organic carbon analyzer

Each of the five existing real-time stations use essentially the same equipment for water quality analysis and data transfer, and do so with relatively little downtime. The current suite is a good *worst-case scenario* for footprint and power demand. That is, if a mobile station were to be installed at a location off the electrical grid, and the designed system could power the current suite, it would likely be able to power any other types of equipment that might be used as a replacement. The current suite analyzers are the Sievers 5310C for organic carbon (Figure 10), the Thermo-Fisher/Dionex ICS 2100 (Figure 11) for anion analysis, and the YSI 6600 V2-4 or EXO 2 multi-parameter water quality sonde (Figure 9). These instruments have been fully vetted by MWQI to operate unmanned in remote locations. As compared to other instrumentation, the Sievers and Dionex analyzers have a larger physical footprint and have higher power demand. They also have more stringent environmental and temperature requirements than probe-based instrumentation, and therefore require additional equipment such as pumps and HVAC systems. The cost for these instruments is approximately $25,000 for the Sievers, $80,000 for the Dionex, and $15,000 for the YSI. With the higher cost and other factors in mind, finding alternatives to analytical instruments is preferred, when possible.

Figure 11. Dionex ICS 2100 Ion Chromatography Instrument

Flow/Discharge Data

Power Demand: ADPC- 12 VDC. Power Requirements: 2-4 watts. Depends on sampling frequency, but 15 minute data frequency and all required peripheral components can be powered off of a 30 watt solar panel and a 12 volt, 75 amp/hour battery.

Figure 12. Acoustic Doppler current profilers

Acoustic Doppler Current Profilers (ADCP) (Figure 12 & 13), used for measuring the water flow past a site, have become more cost effective and easier to install in recent years. The equipment required is site dependent, so those skilled in ADCP install should be involved in the site selection process. The price range for ADCP varies from around $5000 up to $10,500 for basic single instrument kit. The most inexpensive kit has a 5' max depth and 60' max width for a channel of water while more expensive instruments will measure velocity, flow, and total volume for channels up to 16' deep and 325' wide (Joel at SonTek's sales dept., 4/10/2014).

The Flow Monitoring and Special Studies Section within DWR's Integrated Regional Water Management Office has installed ADCP units in surface water channels in and around the Delta. If workload allows, they can be hired to conduct channel surveys. For a tidally influenced channel, the calibration process takes about 25 continuous hours from start to finish, requires a crew of three using three work shifts, and costs about $10,000, including the mandatory overtime. For a non-tidal location, the calibration occurs over an eleven month period; and requires two staff member's time costing roughly $9,000. Stage/flow relationship monitoring qualifies the site for a stage recorder, which along with a velocity indicator, can provide flow data throughout the year. (Dave Huston, Supervisor, Flow Monitoring and Special Studies Section, 4/10-11/2014)

Figure 13. Visualization of ADCP unit in action.

Considering the cost, it is preferred to site the mobile station near existing flow/discharge stations so that adding ADCP systems is unnecessary.

Weather Monitoring

Power Demand: Campbell Scientific Weather Station; 12 VDC. Power Requirements: Varies, but the basic CIMIS weather station with cellular modem can be run indefinitely off of a 12 volt 28 amp/hour battery that is wired to a 20 watt solar panel.

Figure 14. Campbell Scientific weather station

The California Irrigation Management Information System Program (CIMIS) started in 1982 and manages a statewide network of over 120 automated weather stations. CIMIS field operations are located at the Bryte Yard in West Sacramento, next door to the MWQI Field Unit, and staff are available to help with weather station installation. CIMIS stations operate on a 12 volt system and transfer data via a cellular modem, making the addition of weather sensors relatively easy. (Cayle Little, Land and Water Use Scientist, CIMIS Program, 4/21/14)

The cost of a standard weather station system (Figure 14) used by CIMIS is about $6000. The relative low cost and minimal power requirement makes the addition of a weather station to a mobile station very feasible if such information is required.

Monitoring for Invasive Mussels

Power Demand: None, but requires pump to supply water unless installed directly in water body.

Figure 15. Absence/presence indicator tank used for invasive mussel and clam monitoring.

For the past many years, there has been an increasing interest in monitoring for invasive mussels and clams. An absence/presence indicator tank can be installed in a station with no additional power assuming a pump is present. MWQI's current water quality monitoring stations pump more water than is required by the filtration system and analyzers, and that unused portion immediately is returned to the river or canal. This bypassed water is typically 3-7 GPM--more than enough to support an absence/presence indicator tank for zebra/quagga mussels, and possibly for Asian clams. A four to six week interval is required for veligers to grow large enough to be seen with the naked eye, so for shorter durations, a plankton net can be used and periodic samples sent to Scripps lab for analysis. Setting up the observation tank is simple, and the parts are inexpensive (<$1000). Assuming the pump is adequately sized, this is a very simple addition to a mobile station. The Operations and Maintenance Division currently has a plexi-glass tank installed at the Banks station (Figure 15). (Tanya Veldhuizen, 4/19/2013)

Multi-parameter SONDES, FDOM, and probe technologies

Power Demands: FDOM- External Power Supply: 3-15VDC, Power Requirements: <0.3 watts typical
YSI EXO/6600 Series Sonde- External Power Supply: 12VDC, Power Requirements: 1.2 watt peak, 0.1 watt typical. Can run on internal batteries alone for up to 55 days.

As discussed earlier, true analytical instruments are the accepted and most direct method of measuring constituents such as organic carbon and anions, but new technologies have been developed that make measuring with an electrode or optical sensor possible. Commonly called “probes”, these instruments are generally quite small and have no moving parts. This, coupled with low power demand, makes probes ideal for the mobile station concept. Data quality objectives may require more complex analytical instruments, but in most cases the quality of data provided by probes should be sufficient. While these features are especially attractive for use in a mobile station, MWQI has not completely assessed the value of such instruments. Prior to moving in the direction of these unproven technologies, additional work would be needed accessing their viability.

The Banks station has a Turner Designs Cyclops 7 FDOM (Fluorescence of Dissolved Organic Matter) (Figure 16) optical sensor installed in conjunction with a Sievers organic carbon analyzer. The sensor uses the absorption and release of light at specific wavelengths to quantify colored dissolved organic matter. Because FDOM can provide results similar to dissolved organic carbon (DOC) at a fraction of the cost, maintenance, and power consumption, the Turner Cyclops 7 could prove to be a suitable replacement for a carbon analyzer once initial testing is complete. The FDOM sensor cost about $5000 as compared to the Sievers which costs about $25,000. Add to that the annual maintenance and repair costs and the FDOM sensor quickly becomes the economical alternative to an analytical organic carbon instrument.

Figure 16. FDOM probe installed at Banks pumping Plant water quality station.

Additional capabilities

It never fails that once DWR/MWQI installs a station, other agencies and groups will request space for their own activities. Most of the time, allowing another group to install equipment benefits the scientific community and perhaps MWQI in some way. Therefore, if feasible, it is best to plan a portable station for expansion. Doing so leaves the door open for other group’s research equipment, and allows for future expansion by the MWQI program. This said, there is a delicate balancing between efficiency of the station and planning for the future. These options should be carefully weighed.

4.8. Peripheral Systems

Sample Water Pump

Perhaps the largest power demand component in the station is the main water supply pump. Various options are available to move sample water from the water body to the equipment inside the station, but the pump selection should be based on the needs of the internal equipment. That is, from an electrical demand standpoint, the smaller the pump the better.

As an example, the current pump used at the Gianelli Station is a good *worst-case* scenario pump that can be used for the assessment of a mobile station pump system. The *Dayton* (Grainger Part No. 3YU60) (Figure 17) is a continuous duty utility pump that runs on 115 volts AC and pulls 6.5 amps. It is capable of moving enough water at high enough pressure to overcome the head (elevation) difference between the water body and the Gianelli station while still providing enough pressure to meet the requirements of the filtration system and instrumentation. It is a great pump but has a high electrical draw, about 800 watts. Attempting to operate such a pump *off-grid* is possible, but not preferred. In a true off-grid application selecting a lower power demand pump would be optimal. When selecting a pump, it must be continuous duty which means it is rated to run non-stop. From there, consideration must be given to the elevation gain between the water body and the pump, the pressure and flow rate required by equipment in the station, and the pump power demand. Unfortunately, you cannot have a low power demand pump that provides high flow and pressure. There are many options available, so during station design, the pump should be sized in a way that provides the needed flow and pressure at the lowest power demand possible.

Figure 17. Dayton utility pump used to supply sample water to Gianelli Station.

Although not fully assessed by MWQI, it should be possible to build an intermittent pumping system that provides water to instrumentation at set intervals. Doing so would drastically reduce the power demand of the mobile station.

Data Logging Device

Once a station instrument makes a measurement, that data must be stored somewhere. Many instruments, such as YSI sondes have onboard data logging capabilities, but analytical instruments and some probe based instruments require an external data storage device. The simplest way to record data is on a data logger device such as the Campbell Scientific CR1000 (Figure 18). Data loggers are preferred for the mobile station concept due to their low power demand. In simple measurement recording mode, power consumption is only about 0.2 watts.

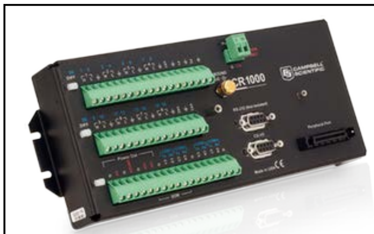

Figure 18. Campbell Scientific CR1000 Data Logger.

With more complex instrumentation, such as analytical instruments, computers can be required to drive the instrument operation and to record the data stream. Desktop computers with monitors have a much higher power demand and consume around 150 watts. Laptops are more efficient, but still consume 60-100 watts. For this reason, non-computer based logging is preferred for the mobile station concept.

Cellular Modem

Data collected at the mobile station most likely needs to be telemetered immediately for analysis, either to assess the data or to assess the operational status of the instrumentation. Various telemetry methods exist, but given the non-permanence of a mobile station, transferring data across a cellular modem, also known as a mobile gateway, makes the most sense. Mobile gateways (Figure 19) are currently used at all of the permanent MWQI field station and are relatively inexpensive (<$500), but do require a monthly service charge. The power demand of such devices is minimal (3-5 watts).

Figure 19. Cellular modem or (mobile gateway) used for transferring station data.

4.9. Security

Security may pose as great a challenge as any other part of the mobile station. Leaving a quarter-million dollar piece of equipment in a remote location will surely raise concerns about vandalism and theft. While some vandalism occurs simply to satisfy someone's destructive urges, a pristine trailer and shelter are usually indicators of valuables inside. Shielding a shelter from rocks and bullets seems simple enough, but not when it comes to protecting a station from a determined thief. Every aspect of the station's construction must be designed with security in mind--from the window-less shelter and tamper-proof fasteners--up to possibly surrounding the station with a razor-wire cage and networked cameras.

Three out of five of MWQI's permanent stations are located in government facilities with 24 hour security patrols and have had no issues with vandalism. The other two are Vernalis and Hood, each of which are buildings mounted on steel piles above the river and are accessible by water, river trail, and levees roads. Due to vandalism and theft, these two stations have been offline for periods of time due to the damage caused by copper thieves. The SMY has made repairs to these stations and installed improved security measures to help prevent future break-ins. Examples of vandals' methods and the resulting preventive measures have been described by the SMY, the Mobile Equipment Office, and the California Air Resources Board. These anecdotes give real, "stranger-than-fiction" accounts of what can happen to equipment in the field, and provide some basis for station design.

With this in mind, during site selection, choosing a site that is near existing structures and in a higher visibility location may decrease the likelihood of vandalism and theft. Aside from the site location, the station shelter should have heavy locks on all doors and equipment cabinets. Motion detectors connected to lights and cameras, along with warning signs, alarms, and bullet-proof plating over the analyzers add defense with not much additional weight or power consumption. Beyond that, the level of security required and achievable is very site dependent.

Security Cage

The best protection for the mobile station is to set up a physical barrier. A simple rent-a-fence built from chain-link panels would not be enough because it is too easy to cut through the fencing (which is what happened at Vernalis) and the posts are only held in place by mildly heavy concrete blocks. A custom cage built by MWQI and the Sacramento Maintenance Yard would yield better results. The cage would be constructed of expanded metal panels, square steel posts and angles, and topped off with coils of razor wire. The cage would be prefabricated at the Bryte Yard and transported to the field in modular panels. The expanded metal panels would have angled steel welded around them to form a frame that can be bolted to the posts from the inside of the cage. On one side of the cage, where the door of the station would be located, a smaller single panel would be modified into a gate with security bolts at the hinges and multiple locks along the other edge. Once the perimeter is finished, another set of framed panels would be bolted across the top of the perimeter. Razor wire coils would be added to the perimeter around the top, with more coils around the door and possibly down the corners. If the location of the mobile station does not allow the use of post holes (such as beside the Aqueduct) to secure the cage, then channel iron skids can be bolted under the posts to add rigidity. The weight of the cage itself is more than a few people together can lift. The station can also be parked on top of the channel iron skids, making it nearly impossible to lift the cage, even with a 3-ton floor jack.

Table 6. Specifications and cost for a security cage 25' long x 10' wide x 10' tall.

Quantity	Item	Cost, each	Weight, lbs.	Total Cost	Total Weight
19	5' x 10' expanded steel panel, ¾", #9R	$70	90	$1,310	1,710
15	3" square tubing, 3/16" wall, 12' long	$61.88	82.44	$928.12	1,236.6
600 feet	2"x2"x1/8" angle steel	$1.19/ft.	1.65/ft.	$715.50	990
4	50' coil of stainless steel razor wire	$40		$160	
400	½" x 5" zinc-plated bolts with lock-nuts				
1	Taxes, 8%			$249.09	
1	Shipping			Free	
Totals				$3202.71	3,936.6 lbs.

Motion detecting lights and cameras may deter many people from tampering with the station, but a ski mask and pellet gun can cut those lines of defense. Locking fuel caps, doors, and hitches can also be a deterrent, but are also easily thwarted by a skilled thief. A large cage built over the entire station can prevent people from getting close enough to do any significant damage, with the exception of the use of high-powered rifles. A Kevlar wrap placed under the exterior sheathing and metal plates behind each of the instruments can keep a lead bullet from piercing the most expensive equipment. The tight pattern of the expanded metal would also be difficult to shoot a bullet through without the bullet deflecting off the cage in some way.

Another way to diffuse a potential vandalism problem is to inform anyone on site of the station's contents and purpose. A sign on the outside of the shelter with a few statements such as:

> "Water quality instrumentation inside; working to evaluate, manage, and maintain Delta resources for the health of California", or
>
> "Sensitive analytical equipment inside; do not disturb. Failure to comply is a violation of U.S. anti-terrorism law ###. If you are reading this sign, your photo is already recorded."

The Bilingual Services Office and the Facilities Maintenance Office within DWR may be able to assist in the translation of statements into a few common languages that can be printed onto metal signs for display outside the station. HAZMAT placards are not necessary for the stations, but are cheap and may play a role in deterring break-ins.

Depending on the location, the shelter may also needed to have some anti-bird perch devices attached to the eaves. Spike-strips, electrical wire-fence, or a raptor statue may deter birds (esp. cormorants) from landing on the station and potentially making large piles of guano on top of the shelter and generator.

All, or at least some of these security measures should be worked into the design of the mobile station. The power demand of some measures, and the cost and weight of all will have some bearing on the selection process. There is definitely a cost benefit analysis to consider when it comes to securing the station and equipment.

5. Equipment and Labor Cost Analysis

5.1. Cost of station construction done by vendors

Vendors were given the specification sheets shown in Appendices 1-4. The first four vendors listed below were provided with spec sheets 1 and 2. The main difference between the two spec sheets related to the choice of trailers and towing options; one allowing MWQI to use its existing truck as a tow vehicle, the other trailer choice allows for more weight but would require a different tow vehicle to be purchased or borrowed. The fifth vendor listed, WSS, was given the spec sheet shown in Appendix 3 because it was their prerogative to use an ISO/shipping container as the shelter for the project proposal. Other ISO container vendors were given a similar spec sheet via email or through their quote request link on their website. Vendor 6, Sundowner, was given the spec sheet shown in Appendix 4, which is more specific to cargo trailers. Despite not having a removable shelter, the cargo trailers are inexpensive, lightweight, and universal in design across varying brand names. CA Air Resources Board has about six cargo trailers set up as mobile CEMS shelters.

Each of the vendors responded with some questions of their own, typically regarding the ultimate function of the shelter, trailer, and power combination. After some back-and-forth, mostly in phone conversations, written quotes were received which contained varying degrees of detail. From some vendors, obtaining the price and build quotes proved difficult; partly due to the uniqueness of the product, but largely to due to the fact that vendors do not get paid to provide quotes and already have paying jobs underway with accompanying deadlines. In the case of bidding on the mobile station, the quotes required some custom electrical system design and weight balance calculations which may have caused some of the difficulty in acquiring the quotes.

The following is the list of companies that were contacted, and who stated they could provide a finished “turn-key” product. Below is a short summary of the pros and cons of each vendor’s approach.

Shelter One http://www.shelter1.com/

$94,000, up to **$100,255** with all of the options and delivery included. Company located in Grants Pass, Oregon.

Pros:

- Quote is detailed with line-item pricing for each options and component performance literature. Includes coverage of all the requirements listed in the provided spec sheet.
- All P.E. stamps and insignias are available, including seismic and energy code compliance.
- Deep discounts available for an order of multiple units, even if it is just more shelters.

- Shelter One has a large portfolio of completed shelters, covering many industries.
- The Gianelli station shelter was built by Shelter One, receiving rave reviews by DWR.

Cons:

- Although the components in the quote were described, and photographs of similar equipment are available, there were no schematics provided with the quote.

Sun West Engineering http://www.sunwesteng.com/

$105,300, plus shipping. Located in Phoenix, Arizona.

Pros:

- Provides emergency off-grid cell towers to remote area or during emergencies, along with UL and NEMA rated equipment cabinets and housings.
- Accustomed to designing portable power supplies for shelters and arranging them on wheels, including solar panels, battery systems, and hydrogen fuel cells.
- Shelter description provided in quote includes seismic Zone 4 rating, high wind load (150mph) for highway travel in windy conditions, non-corrosive hardware, and safety supplies.
- Chosen batteries are for high-heat conditions. A/C unit proposed for battery cabinet.
- Schematics included, show size and arrangement of shelter and cabinets on trailer.
- Many examples of Sun West's completed vehicles/trailers are viewable on the website and even in a newscast, highlighting their contract with Verizon for emergency communication set-ups.

Cons:

- The quote does not have line-item pricing.
- May not have a P.E. stamp/sticker available for the shelter, but that may not apply to a shelter that is UL listed as a "communications cabinet".

EKTO http://www.ekto.com/

$69,600 for basic set-up, $88,225 with most options and P.E. stamps, but no battery system. Delivery is an additional $7,800. Total = $96,025 without the battery bank and inverter. Located in Sanford, Maine.

Pros:

- Pioneer in the portable shelter industry, with great attention to detail included with the quote, including construction and material details, performance ranges, and a schematic of how the shelter fits the transport trailer.
- A wide array of options available, with line item pricing and weight/dimensions.
- Transporter trailer is proprietary, sensible, and can transport shelters with lengths from 8' up to 20', without tongue-mounted generator. Made for shelter deployment using no other equip.
- Quality generator and tank, interim Tier IV approved.
- Zone 4 seismic rating, and P.E. stamps and stickers available.

Cons:

- Due to their East Coast location, Ekto's delivery charge is nearly $8000.
- Despite a written spec sheet and phone conversations explaining the need for a battery bank/inverter/auto-start system, the quote does not include any of these. As a result, the oversized generator would have to run continuously, causing more emissions, refueling, and maintenance required.

Precision Quincy *http://www.pqshelters.com/*

$84, 700 + shipping ($4000-5000) = **$90,000** estimated. Located in Mason, Ohio.

Pros:

- Has been building shelters for twenty years; ISO 9001:2008 certified.
- Contracts with other vendors for trailers and generator systems.
- 150 gallon double-wall fuel tank
- Lightweight, non-oxidizing shelter with lifting lugs. Very similar to that used by O&M.
- 3-point door lock mechanism with stainless steel hardware.

Cons:

- Quote is for a generic railroad shelter that is 8' wide, difficult to transport on some roads.
- The trailer described in the quote is not consistent with the size needed to carry the shelter that is listed in the quote; not the right deck size, with fenders above the deck.
- The language in the quote states: "Quit Diesel Series QD6000 with battery back and transfer switch". "Quit" should read quiet, and "back" should be bank. This quote provides no information about the batteries, inverter, or auto-control switch. There is also no explanation of how these components would be arranged in a mobile application.
- The price quote is not itemized for each feature or accessory.

Western Shelter Mobility *http://www.westernshelter.com/*

$109,290, without shipping. Located in Eugene, Oregon.

Pros:

- WWS does build innovative shelter systems, and although most are based on tents, cargo containers, and Class A truck trailers, they do convert Class C cargo trailers into mobile response and operations centers.
- ISO 9001:2008

Cons:

- The quote and line items are largely regurgitations of the same text (copied and pasted) used in the specification sheet provided to the vendor.
- There is no line item pricing, simply a list of customization charges ending in $0.00.
- The total price is the summation of two charges. $38,600 for the trailer, genset, and battery system, with no description whatsoever. The second list price is for the shelter itself, a converted 8 x 10' container, at $70,690. This is **2-8 times higher** than prices listed online and two other quotes received from other converted container vendors.
- No description or brand names of components to be used, and no schematics of how any of them would be fit together.

Sundowner *http://www.sundownerofca.com/*

~$25,000, local pick-up.

Pros:

- Local vendor with a full service shop on-site. Has working models available for inspection.
- Cargo trailer is a "turn-key" shelter at 25% of the cost of other shelter/trailer combinations.
- A cargo trailer does not need a building permit or P.E. stamps to be legal.
- The interior space is larger than any other shelter proposed in this report.
- Shore lines can connect the electrical system to on-grid electricity.
- CA Air Resources Board has about six in service as CEMS, with no problems thus far.

Cons:

- Power supply limited by small generator size. Propane tanks will need to be exchanged.
- Battery bank/inverter system would still need to be added on and priced out.

- Not as secure as other shelters. "Toy Trailer" style makes it an attractive target for thieves.
- Cannot be used as a permanent shelter, safe up to a year with wheels removed.

ISO Containers

Three vendor quotes for ISO containers were received:

Sea Box: Intermodal Concepts and ISO Shipping Containers http://www.seabox.com/

$26,889 w/o shipping, shelter only.

Pros:

- Sea Box can add any number of features and finish to an ISO container, including their proprietary man-door insert that replaces a container door with a normal steel 3' x 7' door.
- The quote was complete and descriptive of the features desired by MWQI.
- Custom sizes are available, but changing the size of an ISO container is expensive.

Cons:

- Expensive, especially for a converted ISO container. More expensive than the custom shelter ordered for the Gianelli station.
- New Jersey location makes delivery expensive as well.
- No line-item pricing, and the quote includes features that were not specifies by MWQI, features with no individual pricing.

Container Solutions, Inc http://containersolutions.net/

$8500-$9500 including shipping, very basic shelter only.

Pros:

- Fair pricing and good communication and suggestions by the vendor.
- Short lead time, with delivery promised within 5 weeks.
- Close vendor location of Concord, CA and delivery cost of only $300.

Cons:

- Fair price, but not a good price, especially considering the size of the box is unaltered, 8 x 20', larger than what is necessary and more difficult to move.
- The features described are minimal in quantity, quality, and finish.
- Would not fit on most trailers along with a generator.

Cold Box Inc. http://www.cold-box.com/

$3500 plus tax and $475 shipping for a *non-working* refrigerated 20' container.

Pros:

- Good price and further cost savings realized through work that does *not* need to be done: insulation, floor and wall paneling, weather-sealing, and waterproofing interior.
- T-rail flooring is non-skid for safety, high R-value insulation, stainless-steel walls and ceiling.
- Wind and water tight.
- Reasonable delivery charge from Oakland, CA and within a couple weeks.
- *Best value* for using an ISO container as an equipment shelter.

Cons:

- Heavier than normal ISO container weight and size of 20', making transport more difficult.

- 10’ refrigerated units rarely available.
- The area that contained the refrigerator workings would need to framed-in for an HVAC unit.

At the time of this report, the average price from the vendors is $100,000, + or – 10%. This is the price that should be used as a baseline for future station construction costs.

5.2. Cost of station construction done by DWR

The MWQI Field Unit shares the Bryte Yard location with other DWR divisions, including the Soils Lab, Chemical Lab, and Sacramento Maintenance Yard (SMY) section of Flood Management. The proximity to these other groups has been beneficial to MWQI in the form of borrowed equipment and space, technical advice, and especially the ability to hire SMY utility craft workers for construction and transport of materials and equipment. If their schedules allow, the utility craft workers may be hired using internal charge numbers to complete some or all of the construction of a mobile station. Depending upon the ease of procurement and fitment of materials, scheduling, and the quantity of labor required to complete the station, there may be substantial cost benefit to constructing the station at the Bryte/Sacramento Maintenance Yard. At the time of this report, the SMY has been busy with drought related issues, equipment maintenance, flood preparedness, and other construction projects. If the SMY were to build a mobile station they would do so using an ISO container. A specification sheet for a shelter was given to one of the supervisors early in 2014, but due to increasing workload, a formal quote was never received. Assuming that SMY has time for such a project, Table 7 contains a rough outline of the materials to be purchased, price estimations, and a basic list of equipment needed for construction. The SMY has all of the certified workers and experience to complete the build.

Table 7. Estimated Parts and Prices for Sacramento Maintenance Yard construction of mobile station.

Part	Price Estimate	Task
Shelter: Starting with a clean ISO container, sized 8 x 8 x10', possibly 8 x 8 x 20' cut in half at the Yard.	$2000 for 10' container $2500 for 20' container $3500 for 40' container	Pick up ISO with a truck and trailer. Cut container to proper size and weld on a new wall and door.
Metal wall studs/joists	$200	Frame inside of ISO
Insulation: ranging from fiberglass to foam	$150 for fiberglass, R13 $500 for foam, R13	Cut and place, or spray foam insulation
OSB/Plywood walls	$150 - $250, 12 sheets	Attach walls, ceiling
FRP panels for interior	$400, 12 sheets	Glue FRP and strips
Alum. Diamond Plate	$700, 2.5 sheets of 1/8"	Attach to floor
Steel Wall (listed above)	$350, 2 sheets of ¼"	Rebuild wall, if needed
Steel door and frame, preassembled 3 x 7'	$570, insulated	Weld in door frame, if needed
Outer insulation: radiant barrier, foam	$600, higher cost for foil and spray foam	Attach insulation to outside of ISO container
Outer skin: powder-coated aluminum, color	$850, for 12 sheets of 0.040 thickness	Attach skin to exterior of ISO container
Electrical panel: 18 slot, interior, box, cover, breakers	$2000	Set panel in wall and assemble interior with breakers
Conduit, switches, outlets, covers	$500	Install electrical in walls and ceiling
Lighting: fluorescent and HPS, motion detect	$500 inside $500 outside	Hang fixtures on ceiling and at exterior corners
HVAC: Window Unit, ductless, remote, 120V	$1000 1 ton $1500 1.5 ton	Cut opening in ISO and frame in the HVAC unit
Smoke/Heat/CO2 Detector, 120V	$100	Wire in detector
Generator: Quiet Diesel, 10kW, 1800 rpm	$10,000 with enclosure, basic accessories, tax	Mount generator on top of fuel tank/trailer
Double wall fuel tank	$5000, 132 gallon	Mount tank to trailer
Auto transfer switch	$500, 100 amp	Connect to generator
48V Power Inverter	$3000	Connect to electrical sys
Battery tender, 48V	$400	Connect to battery bank
Batteries, 4 total 48V	$800, AGM or lead-acid	Connect to system
Battery housing	$300, for steel and vent	Construct battery box
Battery tender for gen.	$50, 12V for generator	Connect to system
Miscellaneous for gen.	$500, wiring, fuses, etc.	Connect to system
Trailer: 8.5' x 16', 14,000 lb., tandem axle, deck over wheels, wood deck	$5500 for bumper-pull style tongue $7000 for Gooseneck tongue	Set the ISO container on the trailer
Trailer leveling jacks	$200 for 4	No labor involved
Miscellaneous: wiring, fasteners, couplers, etc.	$1000	Part of labor per item or station component
Grand Total for Parts	**$37,820 - $41,770**	

Using the calculated figure of $40,000 for parts and materials; approximately $60,000 would be available for the labor cost of the utility craft workers. That is, over ¼ PY of time would be available to work on the mobile station, or 3 utility craft workers working simultaneously for over a month to complete the project. The amount of required SMY labor time is undefined but would likely to come in below $60,000. The greatest obstacle with this approach is ensuring the SMY have enough time available to complete the project within a reasonable time frame. A project such as this would never be a priority for the SMY, as their foremost function is levee and equipment maintenance. There are certain times of the year when SMY's tasks lull and lower priority projects can be moved forward, but those instances have decreased in frequency.

Another caveat of using the SMY is that the ISO container design would need to be used. Therefore, the finished product would not be as light and maneuverable as a custom, purpose-built shelter. An empty 8 x 10' ISO container has a tare weight of about 3000 lbs. After the addition of the interior paneling, electrical and HVAC systems, and MWQI's equipment, the total weight would be close to 5,000 pounds and too heavy for the SMY boom truck to lift. Therefore, a third-party crane service would have to be hired each time the shelter was to be moved.

All told, the SMY could build a station for roughly the same price as those available on the open market, but the concern is the availability of time to complete such a project. Outside vendors have already worked through the learning curve and design process, and most of them either build their own trailers, or work directly with a trailer manufacturer and receive a wholesale cost savings. So in the end, the SMY is a viable option to fabricate a mobile station, but only if they have time available to do so.

5.3. Total Cost of Mobile Station with "current suite" of instruments.

The total cost of a new mobile monitoring station is the sum of all parts and labor needed to bring the station online and producing reliable water quality data. Since some of the potential components discussed in this report have yet to be fully vetted, it is difficult to estimate the cost of implementation beyond pricing the equipment. Unforeseen cost overruns are more likely to occur on jobs that are not routine. For this reason, this section is limited to listing the cost of equipment currently used by MWQI in the most advanced of its stations, the Gianelli Real-Time monitoring station. The most notable instrument differences between Gianelli and a new station of a similar design, would be the use of a Dionex 2100 ICS anion analyzer and YSI's EXO 2 sonde.

Table 8. Current Suite initial station cost.

Station Component	Total Cost ($)
Completed Mobile Station	$100,000
Dionex 2100 ICS with Sample Prep unit (SP10), computer, preventative maintenance kit and warranties	$85,500
Sievers 5310c	$25,000
YSI EXO 2 (for a completed sonde, minus algal & FDOM probes)	$13,525
Datalogger	$2,000
BPS 4400 Watt Back Up Power System (batteries, inverter, controllers)	$8,000
Generator	$2,000
Generator Auto-start system	$500
Intake Pump	$1,200
Filter Housings	$350
Filters	$200
Pressure Gauges	$200
Purge Valve for air	$300
Tubing	$500
Water Supply Fittings: barbs, tees, wye	$150
Valves & push connectors	$300
Sink	$400
DI System	$300
Cellular Modem	$500
Bench for Analyzers	$400
Work Bench	$400
Safety Equipment: Fire extinguisher, first-aid kit, flotation devices, rope	$500
Misc. brackets, fasteners	$500
TOTAL	$242,725

Table 8 prices are for equipment and materials, but not labor. As in the past, once the structure/shelter is in place and the utilities are connected, the MWQI Field Unit can typically get a new station functional within a week's time without input from other DWR divisions.

5.5. Other Concerns

Without having all of the information necessary, the planning process will be somewhat incomplete until all station needs and constraints have been defined. The following is a list of details that should be addressed once the decision to build has been made.

Vendor Bid Specifications and Pricing: The mobile monitoring station project is not a profound or rare concept and fully functioning examples do exist. That said, there are very few vendors that have experience in all facets of the mobile station described in this report. Of all vendors contacted, only a few expressed the capability and resources to complete the project as specified in the bid request. What was typically lacking from the bids was a battery and inverter system to compliment the generator, and allow for shorter run times by the generator. Before making commitments with any vendor, their bid sheet should be examined by an electrician/engineer to be sure that what is described is possible and reliable. Furthermore, the pricing of the components proposed by the vendor should be checked against going market rates to protect against overcharging.

EPA, AQMD, and Local Energy Codes: New emission standards for generators have been instituted, which may have an effect on the mobile station's generator size and fuel source. It is doubtful that a mobile station would need a generator large enough to have EPA restrictions, but it is a compliance issue of which to be aware. *Green* initiatives, from local, state, and federal governments, may dictate that certain types of insulation or lighting be used for this project. Since power is so limiting in the mobile station concept, green construction techniques should automatically be part of the design. Even so, it is still wise to ensure green codes are being met prior to the beginning of construction.

State and County Building Codes: Building codes may not apply to the mobile station because it is on wheels. If the shelter ends up becoming a permanent fixture (by bolting it to a concrete slab), local codes should be referred to by DWR's Real Estate Branch to ensure the station is in compliance. Building size is the biggest factor in determining the need for a permit. Permits are required for buildings over 120 square feet. Mobile stations described in this report would be less than 120 square feet, unless an unmodified cargo container was used. In such a case, other compliance rules would need to be followed. Aside from size, there are other rules that define whether or not a building is permanent. For example, a structure may not be considered permanent if it is not connected to municipal utilities, and is not an occupied dwelling. These are all things to consider prior to converting a station to permanency.

6. MWQI Field Unit Conclusions and Recommendations

Within the last decade, the MWQI Field Unit has installed real-time monitoring stations nine times. Of these, five occurred in shelters that had minimal provisions for a real-time station application. Needless to say, the Field Unit has gained knowledge that would have impacted the way some of the stations in the past were constructed ("hindsight"), and certainly how future stations will be planned. So, with all of the information gathered within this report, here is a look back to the guiding questions that were intended to be answered:

Is it feasible to build and operate a mobile station?

Not only is the construction of a mobile real-time water quality station feasible, but there are multiple vendors who specialize in just such applications. The need for continuous monitoring of emissions in urban areas led many shelter manufacturers in the direction of providing deployment systems for their customers' shelters. Investigations into natural resources, greenhouse gases, and climate change created the need for remote monitoring, which the shelter industry has obliged by integrating portable power systems, attachment point for towers, and lightweight materials that increase accessibility to remote areas. There are already examples of portable monitoring systems in California, many of which are owned by municipalities for air and water quality investigations. While most of these were designed to operate from grid power near the sources of air pollution and drinking water, the addition of portable power is possible and can be designed in a way to provide the power needed to operate station systems off-grid.

Recommended vendor?

It is the opinion of the MWQI Field Unit that Shelter One is the vendor most likely to provide a dependable product, followed by Sun West Engineering and then EKTO Manufacturing Corp. Each of these companies has given sufficient evidence of their competence, through informational quotes, phone conversations, and a gallery of completed projects. Using these three competitive bids allows for a transaction within the confines of the State's purchasing system. Although the other two manufacturers have their own successful examples and a good reputation in the shelter industry, Shelter One is favored by the MWQI Field Unit for these reasons:

- MWQI has already purchased from a shelter them, with no surprise costs or problems.
- The staff at Shelter One has always made themselves available for technical conversations/consultations at no cost.
- They have functioning examples of mobile stations, with portable power, and have provided the price of each of those stations.
- Shelter One is less than 350 miles from Sacramento, making them the closest vendor by far. This location means they provide many shelters to California and are familiar with CA codes and regulations, and would have greatly reduced transport fees.
- They produced the shelter used at the Gianelli station, which has functioned without issues since early 2012. The plans and provided hardware for anchoring the station were perfect.
- Their product seems superior and the cost was about average for the price range.
- The shelter was delivered within the time frame promised to MWQI, and all of the factory warranties on parts are transferrable.

Sun West Engineering is considered a great second choice based on these factors:

- They have built self-powered stations on purpose-built trailers and produce their own equipment cabinets.
- Sun West has an extensive gallery of innovative products, and the owner had great ideas about powering a mobile station that other vendors had not considered.
- Although located in Phoenix, AZ, they have a CA business license and knowledge of CA building and energy codes.
- They have experience working with municipalities and water districts, including the Salt River Project.
- Their quote was higher than most other vendors.

EKTO Manufacturing Corp. is a good third choice due to these factors:

- They are the originators of the portable equipment shelters, starting over 50 years ago with military contracts and specifications.
- Most other vendors have copied what they produced, including the self-deployment system.
- Line item pricing for options, along with weight calculations.
- EKTO has already built many mobile stations that would work for MWQI's needs.
- East Coast location makes delivery expensive.
- No explanation of a battery/inverter system, as specified in the bid request.

Shelter1 has earned the trust of MWQI by providing a great product through an easy purchasing experience. Thus far, there is no reason not to use their engineers to build a custom shelter system.

Concluded cost and time requirement to get station built?

As listed in Table 8, the equipment cost of a fully functioning mobile station is estimated at $242, 725. Keep in mind that this cost includes all current suite instrumentation which alone make up $125,000 of the total cost. The cost of previous permanent stations far exceeded this price point, so the mobile station concept is the clear economical choice. Once the decision is made to build a station, it will take roughly 12 weeks for the shelter to be completed: 1-2 weeks discussion with vendor, 1 week to finalize plans and accept drafts, 8-9 weeks build time, 1 week for delivery. Once the shelter is delivered, the amount of time required to prepare it for installation in the field is about 4-5 weeks: 2 weeks at Bryte Yard, 2-3 weeks to get the shelter into the field.

MWQI Field Unit recommended shelter and power system?

The final design will be dictated by the data request, along with site and budgetary restrictions. All things being equal, the approach to station construction recommended by the Field Unit is:

- Select the most energy efficient equipment that will still produce the data desired.
- Invest in the insulation and energy saving features of the shelter.
- Maximize the potential for solar arrays: Add a panel over the door and stow extra panels within the shelter while under transport. Deploy these additional panels once the station is parked, allowing the panels to act as an awning over the door and a cover for a generator.
- Shore up the deficiency in energy needs by employing a modest diesel generator.
- A large battery system will store energy for cloudy days and nighttime operations.
- A shelter that is separate from the trailer will allow the station to be lifted and anchored with the analytical equipment in place.
- Analyze for the best performance/cost yield.

Remember that this is an “equipment shelter”, not a workplace for personnel that must adhere to the same regulations and permitting processes as most buildings.

Appendix 1--Shelter Design Specs for Mobile Station Version I

With this version, a 12,000 lb. trailer weight and 1200 lb. tongue weight is the maximum for the tow vehicle, which uses a conventional Class IV hitch with a weight distributing system.

These specs may not be achievable within the weight requirement, which is part of this study's purpose.

The company I represent would prefer that the shelter itself be a separate structure rather than integrate the trailer. The idea is to have a single trailer and power supply that can have shelters loaded and set up for investigations. Once a permanent site is chosen, the concrete pad and on-grid power supply will be constructed and the shelter anchored. Another shelter can then be loaded up and the process repeated as needed.

CA Seismic and code compliance, with the CA seal sticker.

80"W x 120"L x 96" or less H (outside dimensions)

4000 lb. max. Lightest weight possible, please make recommendations.

Well insulated, utilizing the 5.5" wall thickness.

Cut-out for a small window-style HVAC, ~5000btu.

10 amps continuous, with peaks over 30 amps.

1800 rpm diesel generator and 40+ gallon tank.

Battery bank and controller built into the trailer, but not the shelter.

Basic internal conduit with two fluorescent fixtures.

Car trailer construction, to keep it narrow and low to the ground.

FRP over OSB, unless there is a lighter, water resistant alternative.

Diamond-plate floor.

Roof brackets along the eaves for solar panels.

Appendix 2--Shelter Design Specs for Mobile Station Version II

With this version, the tow vehicle will be capable of pulling a 17,000lb. goose-neck trailer with 4,000 lb. tongue weight. It is possible to add 5000 lb. more to the trailer weight and 1000 lb. to the tongue weight if we can procure the right vehicle, and if it is necessary to get the power supply reliable enough, although light as possible is still a goal. Our best model of a refined station is currently operating with the worst-case scenario of power consumption, consisting of 42 peak amps and typically ~10 amps at 120VAC. The largest power draws are from the HVAC and the water pump. The Shelter One we're using has a 2 or 3-ton HVAC system, and the water pump peaks at 7 amps and runs at 4 amps. We are trying to find more efficient alternatives to these two, but the analyzers will have to remain the same for now. The analyzers, computers, and peripherals total 10 separate draws at less than 1 amp each, but they are continuous. Each of our five stations operate on a 24hr./7 day schedule, but can be scaled back if the portable power supply cannot handle the load. Some solar panels can be mounted to the roof of the shelter, but they would only total <100 sq. ft. and most of our locations are subject to vandalism. Flooded LA batteries will work for our needs since we can maintain them, but lithium ion cells are also a possibility for us if the battery management system can be worked out.

The company I represent would prefer that the shelter itself be a separate structure rather than integrate the trailer. The idea is to have a single trailer and power supply that can have shelters loaded and set up for investigations. Once a permanent site is chosen, the concrete pad and on-grid power supply will be constructed and the shelter anchored. Another shelter can then be loaded up and the process repeated as needed.

We would like to keep the shelter weight under 5000 lb., if possible, in order to use our own boom truck, but the final design may not allow this. We'll work around it if need be.

We would prefer a diesel generator because the tow vehicle will also be diesel and we already have an auxiliary tank and transfer pump. A propane set-up would also work since we can simply exchange the tanks. Avoiding HAZMAT issues, high-maintenance generators, and fuel contracts works best for us.

Shelter/Station Features

Gooseneck car trailer to keep a lower center of gravity, with "drive over" fenders to allow for easier loading and unloading of shelters, from Load Trail brand specs. Four or five stabilizer jacks. Wood or steel straight deck.

<5000 lb. shelter: ~6'6" W x 10' L x 8' H, outside dimensions, to fit trailer fenders.

Single 3' x 7' insulated door with triple lock system, facing the tail of the trailer.

Window-style HVAC unit. May also need an AC unit for the battery enclosure.

Motion detect lights on all four corners, LED if possible.

High R-value insulation. Insulated door.

FRP over ~7/16” OSB, unless there is a lighter alternative.

Diamond plate floor. Four D- rings on the skid. Copper ground plate.

Outside panels: ???, something light, strong, and camouflaged ? Suggestions?

Duralast roof: white or light colored.

(4 pr.)Brackets/mounts around the eave/roof, the clear-span truss/strut system.

Steel rodent & moisture sheeting on bottom.

(2) 4’, dual-bulb fluorescent fixtures centered on the ceiling.

(1) 2” through-wall conduit with caps on rear wall near “passenger side” of shelter.

Electrical System: 48V FLA battery bank recessed in deck of trailer, Onan quiet diesel generator and ~40 gallon fuel tank towards the tongue. Auto-start controller, control panel.

(1) 60 amp single phase panel with four 15 amp circuits, one dedicated to the HVAC, quick connect/lock plug for the main coming into the panel.

(6) duplex outlets, three on each long wall, basic exposed conduit mounted at 6’6” on the walls. One circuit/outlet with GFCI outlet.

Anti-Vandal: Locking fuel cap, security door for battery bank, cage for the generator and maybe the HVAC, kevlar wrap. Also looking for suggestions.

<u>List of potential counties where the station could be anchored</u>

Sacramento	Sutter	Santa Clara
San Joaquin	Yuba	Contra Costa
Stanislaus	Napa	Merced
Yolo	Solano	Madera
Colusa	Alameda	Fresno
Kings	Tulare	Kern

If one or two counties have stricter building or energy codes that greatly effect the cost of construction, those counties or zones may be reconsidered.
Example: Some counties may have roof/snow load requirements in their eastern regions*, far from our potential locations in the valley.*

Appendix 3--Specs and questions for design concept build

1) Tandem-axle trailer that carries the power supply with it and uses a locking plug to connect to the shelter's circuit panel. The trailer can be conventional or goose-neck (whichever you recommend for the weight balance
2) Front/tongue mounted diesel generator and tank. Prefer Cummins/Onan or Kubota, John Deere, Isuzu too, engine. Appropriately sized fuel tank (40-50 gal.?80-100 gal) under the generator.
3) 120 volt system. Flooded lead-acid batteries (2V cells, 48V total, ?), mounted under the shelter, with the inverter/auto-start controller in a weather-tight box somewhere on the trailer. 50 amp peaks, 12-15 amp continuous duty capability. Single panel mounted close to the door with 4 – 6 slots/breakers, 15 amp; maybe one 20 amp breaker for the water pump or HVAC.
4) ISO smooth exterior, insulation, FRP over OSB, CAT. 5, etc…
5) White exterior, White interior.
6) Non-skid, waterproof flooring. I'm OK with the
7) Original double doors and a security can over the lock, but maybe you have something better.
8) Two fluorescent fixtures, each with two 48" T-8 bulbs.
9) Duplex outlets (three each on the long walls, one each on the short walls) with the conduit located at 78" above the floor.
10) High R-value insulation.
11) Basic window-style HVAC (someone will inevitably shoot the HVAC, so I need something I can replace by myself). I'm more concerned with cooling the shelter than heating it.

Appendix 4--Mobile Station Design Specs for Sundowner/Wells Cargo Trailer

We are looking for a vendor that can provide a turn-key trailer with the following features:

16' x 8.5' with 12" added to overall height, to make it 7'6" inside.
.040 exterior skin, unless thicker is available.
Line and insulate ceiling, walls, and floor. Upgrade walls and floors to FRP or press-treated.
LED safety package, spare tire & wheel with subfloor carrier.
36" side door, full-length awning. Bedliner sprayed on floor and 12" up on walls.
Nose cone, four roof racks with adjustable verts.
Heavy-duty vice-lock with double doors in the rear.
Four stabilizer jacks and a 20" fold-up step.
Flow-through vents and roof vent with exhaust fan and cover.

Self contained power system using:

Cummins/Onan quiet diesel generator, fuel tank, auto-start controller, a battery bank, inverter.
A single 50-60 amp panel with three to four 15-20 amp circuits, one dedicated to the HVAC.
Six duplex outlets and basic exposed conduit, mounted at 6'6" on walls.
Two exterior lights, LED preferred, but halogen is OK.
Roof mounted AC unit, baseboard heater.
Our electrical needs: 10 amp continuously used by our equipment 24 hours/day.
The peak amperage could approach 40 amps if all equipment was started simultaneously, but this can be avoided, and we may be able to use a 30 amp panel if that is all that is available. We may be able to switch generator fuel type if necessary. A lighter weight trailer is obviously desirable, but reliable power is the priority. Our truck is capable of pulling a 12,000 lb. conventional trailer or 17,000 lb. gooseneck, just for reference, but a conventional trailer would allow us to keep the service body on the truck.
Anti-vandal: Please make suggestions about protecting the trailer and contents. We will have cameras with live data stream, razor-wire, jacks to remove the tires, chains, welders, etc.

Call Arin Conner at (530) 604-5669 with any questions or suggestions to finalize this quote.