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A design for a practical soil bed disposal system for pesticide contaminated wastewater

Jason Carroll King

To the Graduate Council:

I am submitting herewith a thesis written by Jason Carroll King entitled "A design for a practical soil bed disposal system for pesticide contaminated wastewater." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering Technology.

William E. Hart, Major Professor

We have read this thesis and recommend its acceptance:

Daniel Yoder, Ronald E. Yoder

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A DESIGN FOR A PRACTICAL SOIL BED DISPOSAL SYSTEM FOR PESTICIDE CONTAMINATED WASTEWATER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Jason Carroll King

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For Cheri Lynn,

...you are the names of things.
-Robert Haas

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ABSTRACT

Pesticide rinsate disposal is an ongoing problem for today's farmers. The legal and environmental repercussions resulting from mismanagement of pesticide wastewater can be great. A simple, inexpensive, and legal means of dealing with this issue would be of benefit to many producers. The goal of the current study is to develop a facility design that incorporates a mixing and loading facility with a practical, effective pesticide wastewater disposal system.

The first component in any comprehensive pesticide wastewater management plan is to minimize production of rinsate. Proper calibration, in-field rinse systems, and rinsate recycling can greatly reduce the amount of rinsate created during chemical application procedures. Unfortunately, some rinsate production is inevitable. Containment and collection of this waste is the next step in the safe handling of rinsate. Pertinent research with regard to chemical containment and storage was reviewed in detail. A rinsepad structure was chosen as the most effective and economical means for rinsate containment. Having decided on a containment technology, a number of disposal options were considered and criteria were developed for choosing an appropriate system. The most effective and practical disposal option was the Soil Bed Bioreactor System (SBBR) developed by researchers at The University of Tennessee.

Having chosen the mechanism for containment and disposal, a facility design was developed that integrated both of these functions. The Plant Science Unit at the Knoxville Experiment Station was used as a case study for this investigation, but the

basic design elements of this facility can be applied to any operation in which rinsate is produced including golf courses, nurseries, and lawn care companies. A rinsepad structure was designed for use during the loading and rinsing of spray equipment. A full-scale SBBR system was designed to dispose of all pesticide wastewater generated at the Plant Science Unit. All pertinent regulations were investigated and complied with. Environmental protection was a major concern in the development of a design. Finally, the practicality of the system and the possibility of use by producers as well as other agricultural end users such as nurseries and landscaping companies were considered.

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INTRODUCTION

Research Justification

A few years ago a problem arose at a Wisconsin dairy farm (Maltsberger, 1995). An unusually high concentration of certain pesticides had been detected in the farm's well. The source of the problem was assumed to be located somewhere on the farm. An investigation by staff of the Wisconsin Department of Agriculture uncovered some surprising results. Having made several chemical applications to his crops, the owner of the farm failed to properly dispose of his pesticide containers. He simply stacked them beside the barn and left them to deal with later. Unfortunately, these containers were laid directly under the drip line of the barn's roof. So, as the rains came, the unrinsed containers contaminated the resulting runoff. The contaminated water then flowed into a small culvert and ultimately onto the well recharge area, causing a significant problem. In fact there were atrazine concentrations of 40,000 ppb found in the soil along the culvert.

Unfortunately, these problems are not isolated. In fact, the Environmental Protection Agency (EPA) has reckoned that 10 percent of all community wells and 4 percent of all private wells are contaminated by some type of pesticide residue (Adams, 1992). Often these problems can be prevented if proper chemical handling practices are applied. If the Wisconsin dairy farmer had triple rinsed his pesticide containers and disposed of them properly, his problem could have been avoided. Also, chemical handling problems are not limited to production agriculture. Golf courses, nurseries, and lawn care companies use a significant amount of pesticide, so it is important that these types of operations practice safe handing procedures for chemicals as well.

Pesticide containers are only one of the wastes associated with pesticide use. One of the most prevalent agricultural waste problems is the safe disposal of pesticide rinse water or rinsate. Hofman and Kammel in Midwest Plan Service Publication 37 define rinsate as "water, and sometimes solids, contaminated with pesticides or fertilizers of relatively low concentration (less than field strength) that is collected in the sump of a mixing/loading pad or secondary containment dike" (MWPS, 1991). The term rinsate is also often applied to the water left in a spray tank itself after rinsing procedures have been completed. Rinsates are composed mostly of water, but there are low concentrations of pesticides present: therefore, rinsate cannot simply be thrown out.

There are many possible sources of rinsate, some of the more common of which are listed below (MWPS, 1991):

- rinse water from the washing of sprayers and tractors used for pesticide application;
- rinse water from sprayer tanks;
- rinse water from empty chemical containers;
- rain or other precipitation which comes in contact with a mixing/loading facility's floor or sump; and
- water resulting from spill clean-up operations in a mixing/loading facility.

There are numerous methods of dealing with this issue. The most obvious is to minimize the production of rinsate. In fact, the minimization of rinsate production must be the first step in any effective solution to this problem. There are three basic techniques for significantly decreasing the amount of rinsate produced on a typical farm.

The first method for reducing rinsate production is the careful calibration of sprayers prior to field application, so as not to mix more product than is necessary. Calibration is the simplest strategy for reducing rinsate production, yet many times it is overlooked. There are five things the applicator must know in order to calibrate properly. This information includes the application rate desired, the size of the application area, the operating speed of the sprayer, the swath width or effective nozzle spacing for the spray rig, and the actual application rate provided by sprayer nozzles at the time of the application. If the pesticide volume mix is limited to the amount necessary to effectively cover the target field, then there will be little or no excess solution to process after the application.

After a chemical application, even if a proper calibration is performed, it is still necessary to rinse the sprayer lines, nozzles and tanks to rid the system of any chemical residue. Unfortunately, this operation produces rinsate. Disposal of this rinse water must be done in a manner consistent with label instructions and environmental regulations.

In-field rinse systems are an effective tool that can be used to rinse sprayer tanks, lines and nozzles without producing a rinsate disposal problem. One such system has been developed by Hart et al. (1991) at The University of Tennessee. This rinse technology is quite simple and can be easily integrated into a farmer's application equipment. In this system, an additional tank is mounted on the spray rig. This tank contains clean water which is used to rinse the sprayer after an application. With some simple plumbing modifications the sprayer pump can be used to pump the clean water through a rinse nozzle into the chemical tank. The action of the rinse nozzle cleans the tank and produces a small amount of excess rinsate. The resulting rinse water can then be applied to the same field or another target crop, provided its application does not exceed label rates or conflict with label instructions for the chemical used. Dealing with rinsate in the field can, in many cases, eliminate much of the problem of rinsate production during rinse operations.

A third option for rinsate management is to store the rinse water and recycle it as a diluent for future applications. This method is especially useful if a sprayer is rinsed and the rinsate cannot be reapplied to the field, or if the sprayer is rinsed back at the mixing/loading area. Because rinsates are generally very dilute, rinsate can be used as diluent for future spray mixtures. However, rinsate should be kept to 5% or less (by volume) of the total spray mixture (Rester, 1988; Taylor et al., 1988). Active ingredient amounts in rinsate are generally unknown, but tests have shown that if rinsate volume is restricted to 5% in new spray mixtures the possibility of applying too much active ingredient can be virtually eliminated. Also, if this technique is used it is very important to segregate rinsates from incompatible pesticides. Tanks must be clearly labeled and accurate records must to be kept to prevent the accidental mixture of mismatched chemicals.

All of these practices are essential to the safe handling of agrichemicals, but they do not entirely solve the rinsate problem. There are many instances where more rinsate is produced than can be applied to crops according to the label rates. For example, calibration errors do occur, resulting in excess chemical mixture. Label instructions or rate limitations may prohibit the application of this excess mixture to another field or crop. Another example is a grower who cultivates many different crops. In general, the more crops produced, the more chemical formulations are used. When there are numerous changes in chemicals or target crops, spray tanks have to be rinsed more often and more thoroughly, increasing rinsate production. It may not be possible to reapply all of this rinse water to the field. Equipment limitations with in-field rinse systems can be a problem as well (Corwin, 1996). For example, it is not possible to wash the outside of a sprayer on location with an in-field rinse system, yet washing the external parts of a spray rig can produce a significant amount of rinsate.

Furthermore, rinsate storage systems can become quite complicated. Chemicals have to be carefully segregated so as not to cause a synergistic chemical reaction or crop damage when they are used as make up water (MWPS, 1991). Rinsates which contain strong cleaning agents, such as bleach, cannot be recycled as make-up water. Also, label instructions for some pesticides prohibit the use of rinsate as a diluent. Keeping track of all these issues requires careful record keeping and diligent management, or a storage plan will not be effective. Many times farmers are unable or unwilling to devote enough time to this procedure. Rinsate storage systems also require a large amount of secure, indoor storage space, which is often not available on the typical operation. Overall, rinsate storage is an effective rinsate management technique, but it cannot solve all rinsate problems and the intensive management involved makes it too time consuming for many producers.

Since some rinsate production is inevitable, one part of an integrated pesticide management system must be a simple, economical and safe method to dispose of these wastes. Disposal options fall into one of two categories: off-site disposal or on-site disposal. The number of off-site disposal options is limited. Even though rinsates are principally water, in many cases they are considered hazardous waste by the federal government. Rinsate is considered hazardous if it contains a chemical classified as hazardous by the EPA or if the content of the rinsate is not known (Noyes, 1991; Dwinell, 1993). Most agricultural pesticides are not hazardous, but a few commonly used ones are, such as 2,4-D. Also, if two or more chemicals or rinsates whose identities are not known are combined in a containment sump, the resulting mixture is considered hazardous by the EPA. Consequently, they cannot be disposed of in an ordinary landfill. Hazardous waste must be taken to a licensed contractor who accepts these types of wastes. The transportation to, and disposal in, a hazardous waste facility introduces the producer to an inordinate amount of regulation, cost, and general hassle. In most cases, off-site disposal is not a viable solution.

The next best option for disposal of rinsate would be a simple on-site disposal method. Ideally, this system would consist of a mechanism for collecting rinsate and then effectively disposing of this waste. The implementation of a system such as this would be of great benefit to applicators for several reasons. First, at present most applicators do not have a plan for dealing with pesticide waste. As a result, rinsate is often handled improperly. As the number of regulations and environmental concerns increase, this option will no longer be possible. Second, an on-site system, if designed properly, will greatly decrease the cost of disposing of rinsate. Costs for disposing of hazardous waste off-site are about $500 to $1000 per 55-gallon drum, not counting the cost of transportation or the extra time and labor required to keep adequate records and comply with all current regulations (Dwinell, 1993). This is simply too expensive for most applicators. Finally, the use of an on-site system such as this would greatly reduce the problem of pesticide contamination of surface and ground water.

Objectives

Principally, this project attempts to economically address the problems of pesticide rinsate containment and disposal. Specific objectives can be defined in two parts: a mixing and loading facility design and a wastewater disposal system design.

Three important objectives can be defined for the mixing/loading facility design. They are as follows:

- Develop an economical mixing/loading facility design that will effectively collect rinsate from rinse operations and deliver the rinsate to the disposal system;
- Design the facility such that total containment of all contaminated waste water is achieved;
- Craft the design specifically to meet the needs of the Plant Sciences Unit of the Knoxville Experiment Station (Tennessee Agricultural Experiment Station) in Knoxville, TN, where the facility will be built.

The wastewater disposal system investigated by Corwin (1996) and Glover (1998) will be used to treat the pesticide rinsates collected in the mixing/loading facility. Three specific goals for the disposal system design are as follows:

- Integrate the technology developed by Corwin and Glover into an effective, full-scale rinsate disposal system;

- Ensure compliance with all pertinent federal and state regulations and important safety practices.
- Make the facility as practical and inexpensive as possible, without compromising safety or disposal effectiveness.

CHAPTER 2

BACKGROUND

Rinsate Containment

For most farm operations, the places most likely to contribute to pesticide pollution are the mixing/loading area and the tank rinsing area. These are the locations where accidents such as spills are most likely to occur. Over time, the residues from previous spills and rinses can concentrate in the soil. As precipitation falls and infiltrates into the ground, these contaminants are drawn into the soil with the water. In some cases these contaminants eventually reach the water table. Areas with high water tables or sandy soils are especially at risk. In the worst cases, these pesticide laden wastes are moved directly to surface water by runoff from storms. A recent study has noted that up to 90 percent of all water pollution problems resulting from agricultural chemicals can be traced back to improper handling practices at the mixing, loading, and rinsing areas on farms (Veenhuizen and Ozkan, 1993).

Problems resulting from this type of contamination include harm both to the environment and to people. In the environment, reduction in fish and plant populations are only a few of the possible results of pesticide pollution. For humans, the effect of pesticide contamination is not always obvious. In most cases, surface or ground waters are not polluted to the degree that acute health affects will result. The problem that concerns many scientists today is the long-term affects of exposure to low doses of pesticide residues (Harris et. al., 1997). This type of low concentration pollution is very difficult or impossible to remedy (Homan et al. 1997).

Another problem pesticide contamination poses to applicators is the legal issues it raises. Environmental regulations continue to tighten as awareness of this problem increases. Olexa (1995) notes that the clean-up costs for mixing and loading areas can be extremely high. He goes on to state that "while farmers and ranchers have not yet been specifically targeted by regulatory agencies, other agricultural-related enterprises, such as nurseries and golf courses have." It is only a matter of time before farmers too may be subject to the same regulation. This could be an enormous burden for any agricultural producer. Thus it is in the best interest of the environment, others, and the farmer himself to insure that agrichemicals are handled properly.

Rinsepads

Because of the increasing concern over groundwater contamination from pesticides and rinsates, mixing/loading facilities (commonly referred to as rinsepads) are becoming more common on farms. The primary purpose of this type of facility is to prevent wastes, especially rinsates, from coming in contact with the surrounding soil or surface water. If these contaminants can be effectively contained, they cannot harm people or the environment.

Kammel (MWPS, 1991) lists three features essential to any rinsepad design. First, the rinsepad facility must plan for the containment of the minor, everyday spills and accidents which occur when mixing, loading, or rinsing a sprayer. These problems define the main purpose for the facility: preventing the gradual accumulation of contaminants in the soil around the mixing/loading area. The second purpose for the rinsepad is to provide secondary containment for any major problem, such as a storage tank failure. In the event of this type of problem the rinsepad must be capable of holding the chemical until it can be removed. The final purpose for any rinsepad is to provide a means for collecting and storing spills and rinse water. After rinsates are collected they can be stored for reuse, applied to an appropriate field, or disposed of properly. If the facility is properly designed to meet all three objectives, contamination of the environment is very unlikely.

The first decision that must be made in the design process for any mixing/loading facility is its location. The site chosen will have a significant impact on the effectiveness and utility of the facility. Waskom and Yergert (1994) note that the safety of people and the environment need to be the first considerations in determining a site for a new facility. An example of a human factor would be the proximity of a site to houses, schools, and other public buildings. In some locations, setbacks from roads or property lines are mandated by local building codes, but in many cases this decision is left to the designer. Depth to groundwater, soil type, runoff characteristics, and distances to well heads are also important factors in the decision process. Because of the risk involved with agricultural wastewater and rinsates extreme care must be taken in choosing a site.

For most rinsepads the pad itself is constructed of concrete. Concrete is an excellent material because it is relatively impervious and can handle the traffic of heavy machinery. Typically the concrete is also coated with some type of sealant to further insure that rinsates will be contained. A curb is provided around the perimeter of the pad to increase the containment capacity of the structure. The pad floor is sloped to provide positive drainage to a sump. From this sump, rinsate can be pumped to a storage tank or disposal system. Often a pesticide and rinsate storage area are integrated into the facility (figure 1) (MWPS, 1991; NRAES, 1995). The size of the pad must be determined by the equipment and the nature of the operation that the facility will serve. Electrical service is sometimes included in the design, depending on the size and scope of the structure. A water supply is also incorporated into the design, but great care must be taken to protect the water source from backflow (Nesheim, 1993).

Safety is another essential ingredient in a successful mixing/loading facility. The well being of the workers who will be using the facility must be carefully thought out. If the rinse pad is enclosed, adequate ventilation must be provided by either natural or mechanical means (NRAES, 1995). Security is also an issue that should be addressed in the design process. Unauthorized use of or vandalism at a pesticide storage or handling facility could cause significant personal injury or environmental damage. In case of an accident, emergency showers and eyewash facilities must be available to workers. A comprehensive emergency plan should also be developed which would include what to do in case of a fire, chemical spill or other accident.

Finally, the issue of secondary containment of chemicals and wastewater must be reviewed. Containment of contaminants is the principle purpose of any rinsepad; so special care and planning are needed to insure that all possible escape routes for wastes or spills have been cut off. The first concern with regard to containment is the volume of material the pad might have to contain. The common rule of thumb in designing for containment volume is to plan for holding 110% to 125% of the largest tank in the facility (Broder, 1990). This will assure that in a worst case scenario, such as a total tank

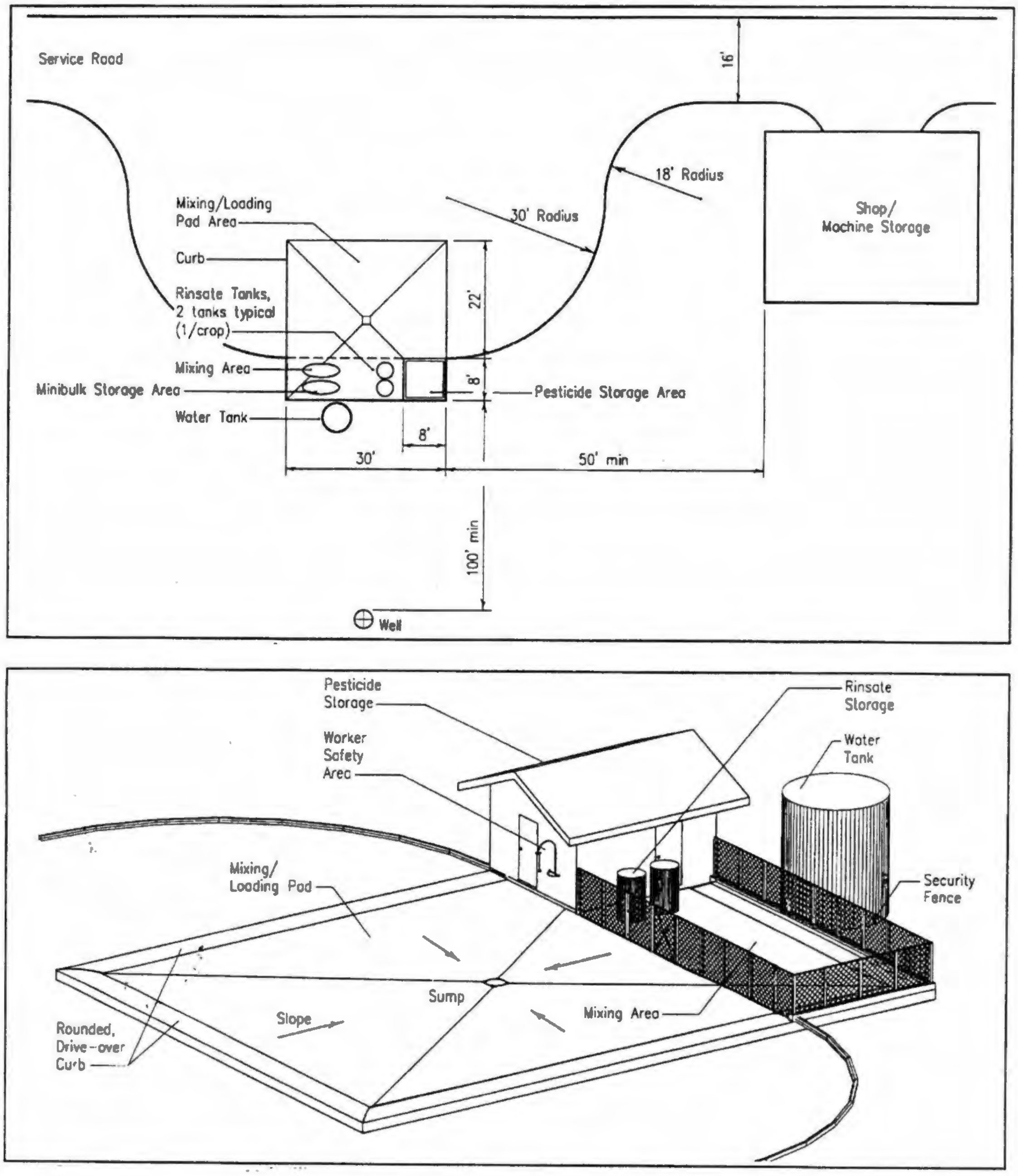


Figure 1. A small-scale rinsepad design (MWPS, 1991).

failure, the problem will be adequately contained. It is important to note that some states mandate containment volumes. Therefore, the regulations for the state in which a rinsepad is to be built have to be investigated. Other containment issues, such as spray mist from rinsing operations, sump overflows, and expansion joint integrity are important considerations as well.

A properly designed mixing/loading facility is a prudent defense against pesticide contamination of soil and ground water. Rinsate production as well as minor chemical spills and accidents are an unfortunate result of modern agriculture's increasing reliance on pesticide technology, but a good rinsepad can minimize the impact of accidents and provide a mechanism for reclaiming and disposing of rinsates.

Treatment Methods

Over the past twenty years, there have been many attempts to develop a wastewater disposal system that would be practical and effective for use by farmers. Corwin (1996) and Glover (1998) note that these systems fall into 1 of 4 general categories: physical methods, biological methods, chemical methods, or combination methods.

Physical Treatment Methods

Physical treatment methods for contaminated wastewater typically use some type of physical filter to separate contaminants from water. One common physical method makes use of carbon as a filter (Zuskin, 1998). These filters use activated carbon that has been processed for increased absorption. The carbon's action is much like that of a sponge. As wastewater flows through the filter, pesticide wastes are trapped in the millions of pores within the carbon medium, and the clean water passes on through the filter. This method works especially well for organic molecules with certain structures, high molecular weights, and low water solubility. Once the filter has been spent, the carbon must be reactivated and the waste material collected must be properly disposed of.

Chemical Treatment Methods

Chemical methods include hydrolysis, oxidation, and precipitation (Zuskin, 1998). Hydrolysis is a common chemical process that can be used in the treatment of wastewater. These systems capitalize on the unique properties of water, namely water's polarity. The basic idea is to use water to break apart wastes into less harmful constituents. These less harmful substances can then be processed much more easily than the original compounds. In oxidation treatment systems, oxidizing agents are added to wastewater in order to change the chemical makeup of the compounds. The goal again is to produce less harmful products. In precipitation methods chemicals containing sulfides or hydroxides are added to the waste stream. The compounds in the rinsate react with the added chemicals to produce a precipitate. The precipitate can then be filtered from the water and disposed of, leaving clean water behind.

Biological Treatment Methods

Biological treatment methods employ the help of soil microorganisms or other biological agents to digest and breakdown harmful wastes. Craigmill and Winterlin

(1988) have defined biological degradation as the breakdown of waste materials by microorganisms, plants, and or subcellular systems that originate from living cells. The strategy of this type of system is to allow biological agents to attack and breakdown the compounds in the rinsate (Corwin, 1996). Again, the goal is to produce less harmful products that can be disposed of simply.

Combination Treatment Methods

In many cases a combination of treatment methods are used in series to provide a more effective system. One of the most promising combination technologies that has come about over the past 20 years is the soil evaporation bed. It relies on a combination of biological and physical processes. The crux of these systems is a soil bed to which wastes can be added (Baker and Johnson, 1984; Vanderglas, 1988). The soil bed itself can take many forms. In the past, pits lined with concrete or plastic have been used (Egg et. al., 1980). This practice has been discontinued because of environmental concerns. A failure of this type of soil bed system would inevitably result in soil contamination. Regulatory issues also discourage the use of this design. More recent soil bed systems, such as the one investigated at Texas A&M, use an elevated soil bed design (Brown, 1986). With this design, the soil bed can be made of any material so long as it is resistant to corrosion and is sturdy enough to handle the weight of the soil and rinsate without cracking. The soil bed is then elevated above the floor of the facility on a frame. Installing the soil bed off the ground allows for visual inspection of leaks, thus assuring containment of the waste material.

The two basic aims of any rinsate disposal system are volume reduction and chemical degradation. Soil bed systems attack this goal in two steps. First, the volume of the waste is decreased due to the evaporation of the water, which is the principal constituent in these wastes. Secondly, the chemical parts of the solution are degraded biologically by the microbiotic organisms in the soil column. One of the best known of these systems was investigated by Charles Hall at Iowa State in the 1970s (Hall, 1984). There has been considerable interest in this technique in recent years and a number of new designs have been developed (Brown, 1986; Winterlin et al., 1989; Somich et al., 1990; Corwin, 1996; Glover, 1998).

Choosing an Appropriate Disposal Method

Criteria

The question still remains: do any of these systems work well enough to be used by farmers? Dwinell (1992) lists four questions that need to be asked when evaluating any rinsate treatment system. First, how expensive is the system to build and operate? Farmers simply will not use a system that is too expensive. Second, how complicated are they to operate? Complicated systems require extensive training and time, both of which most farmers do not have. Third, does the system work effectively? A malfunctioning treatment system could lead to major problems, including environmental contamination that could be very expensive to clean up. Finally, does the system comply with all federal and state regulations? Expensive fines and even imprisonment result from breaking these regulations.

Analysis of Treatment Methods

Reviewing the systems above, the only one that positively answers each of these four questions is the soil bed degradation system. Both the physical and chemical methods are expensive to build and operate. Initial costs for building a carbon filtration system can be anywhere from $20,000 to $50,000 (Dwinell, 1992). Another cost involved is disposing of or recharging the carbon filter when it is spent. Additionally, any sludge which collects in the filter is considered hazardous waste and must be taken to a properly licensed landfill (Noyes, 1992). The filtered water must also be dealt with properly. It is usually not considered clean enough to simply release to the environment; therefore this water must be saved and used as makeup water for a future application. Storing the filtered water adds another layer of management to the system. Physical and chemical methods are not only expensive to construct, but they are also complicated and require a good deal of time and effort to manage. Biological methods are a valuable means for the degradation of waste chemicals. Unfortunately, biological systems alone do not efficiently reduce waste volume. Considering the answer to the first three questions, one would have to determine that most physical, chemical, or biological systems would not be practical for use by most farmers.

On the other hand, the soil degradation systems meet all of these three criteria. The startup cost is relatively low. All of the materials are easily obtained locally, and of course the major constituent, soil, is free. These systems are relatively simple to use. Once constructed, the beds are loaded with wastewater and left alone to do their work. Periodically checking the system for leaks or other malfunctions are the only major management requirements. There have been numerous tests of these types of systems and all indications are that they work well (Corwin, 1996; Glover, 1998; Somich et al., 1990; Vanderglas, 1988).

Regulatory Issues

Unfortunately, answering the fourth question posed by Dwinell is not simple. Determining the legality of any rinsate disposal system can be quite frustrating. There are four federal laws that are relevant to the use of such a facility: the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); and the Clean Water Act (CWA) (Dwinell, 1993).

FIFRA

FIFRA is the primary law that regulates the production and use of pesticides. Enacted in 1910, its original purpose was to prevent a company or individual from selling a counterfeit product (McKenna and Cuneo, 1993). It insured that what the container claimed to contain was really present. It has been amended several times over the past 89 years. In 1947, FIFRA was amended to include mandatory registration of all pesticides and the placement of warning labels on the pesticide container. The law has been considerably strengthened since 1947, with all regulatory enforcement responsibility given to the Environmental Protection Agency (EPA). It is illegal to use a pesticide in a manner that is inconsistent with the label instructions.

RCRA

RCRA regulates the methods of treatment that can be used for hazardous wastes (Dwinell, 1993). Hazardous wastes are identified in 40 CFR part 261 based on certain characteristics such as corrosivity and flammability. If a substance is deemed hazardous it cannot be disposed of in a normal landfill or dump. A licensed hazardous waste contractor must be employed to dispose of these wastes. Most pesticides commonly used by farmers are not considered hazardous, but there are some notable exceptions such as 2, 4-D. Also, unknown mixes of chemicals, which can sometimes be the case with pesticide rinsate, are considered hazardous.

CERCLA

CERCLA requires that releases of hazardous materials, above certain levels, be reported to local authorities and that those releases be investigated and cleaned up. This law is commonly referred to as Superfund. Under CERCLA, the EPA has broad authority. It can require investigations of contaminated sites and force the owner to pay the costs for both the investigation and the clean up. Needless to say this can become extremely expensive.

CWA

CWA regulates the discharge of pollutants to surface water bodies. This also includes runoff from agricultural facilities because it is assumed that contaminated runoff will eventually reach a stream, river, or lake. No discharges are allowed without a permit that details the allowed concentrations for any release. Rinsate cannot be legally discharged to any surface water body.

Determining Compliance of Soil Based Systems

For soil bed based treatment systems, the compliance problem can be broken into two areas: providing secure containment and complying with RCRA. If a facility is properly designed, the pesticide rinsate will never come into contact with the environment. If the waste does not contact the environment, surface water bodies cannot be contaminated, there will be no local authorities to notify, and label application rates will not be exceeded. This insures that the facility complies with CWA, CERCLA, and FIFRA. If all precautions are taken in the design of a facility, such as providing extensive secondary containment, releases should not occur, thus insuring that all laws are obeyed.

Complying with RCRA is not as straight forward. RCRA requires that any waste disposal system that handles hazardous waste must be licensed. There are certain exceptions for farmers. First, if the chemicals to be treated are not considered hazardous, the system is not directly affected by RCRA. If hazardous materials will be treated, but the disposal system is a closed loop with no waste water released to the environment, under the RCRA such a facility can be considered a "recycling" system (Dwinell, 1992). Under 40 CFR 261.2 the waste that is circulated through such a facility would no longer be considered hazardous (Dwinell, 1992). In the case of the soil bed degradation systems, wastewater is added to the system, the volume is reduced, and the chemical is degraded. No waste release is involved; therefore it can be considered a closed loop system.

Soil Bed Bioreactors

Daniel Yoder (1999) along with other investigators at The University of Tennessee (Corwin, 1996 and Glover, 1998) have developed a new soil based rinsate disposal method for which they have coined the name Soil Bed Bioreactor or SBBR. It combines the physical process of evaporation and the biological action of microbiotic life in the soil to effectively reduce rinsate volume and degrade the problem contaminants.

Corwin's Experiment

In the early 1990s superintendents at various Tennessee Agricultural Experiment Stations expressed concern about proper handling and disposal of pesticide wastes such as rinsate. They approached the faculty of the Agricultural Engineering Department at The University of Tennessee looking for possible solutions. In 1992, several researchers headed by Daniel Yoder began an investigation into this issue. They outlined four specific steps that needed consideration to find an appropriate answer to the problem of rinsate disposal. The first step in this process was to make an extensive research effort to find out what options were currently available for rinsate disposal. The second step was to choose an appropriate technology based on research findings. The third step was to identify ways to optimize the chosen technology, making it compatible with farm operations and effective for the disposal of rinsate. Finally, a pilot scale apparatus utilizing the chosen technology was to be built and tested.

The investigation of existing technologies included an extensive study of physical, chemical, biological, and combination treatment methods. Factors such as effectiveness, safety, and economy were important criteria in the judgement of each method. Having reviewed numerous systems, the researchers felt that the soil based systems held the most promise for agricultural applications. They note several reasons for this choice. First, the underlying technology behind the soil bed systems is quite simple, making it much easier for growers to install and maintain than most other treatment options. Secondly, these systems work. All the research so far on these types of systems have produced positive results. Finally, there is no outgoing waste stream involved with these systems. Therefore, no further action or expense is necessary after the rinsate is delivered to the system.

In their study, the team of researchers noted some problems regarding previous investigations of soil based degradation designs. The basic issue with the earlier studies was that the experimental designs did not include a high degree of control. Wastes were essentially dumped into the system with little or no attempt to optimize the environmental conditions. Therefore, Corwin in 1993 continued this research with a lab scale investigation into the evaporative soil bed idea with a specific focus on optimization of the system.

Soil columns constructed of 4-inch diameter PVC pipe were used to simulate a full size soil bed. Two column heights, 10 inches and 7 inches, were used in the experiment. Corwin designed and constructed a large testing apparatus at The University of

Tennessee that could be used to control the environmental conditions on the soil columns. Five environmental factors were tested. These factors are listed below:

- 2 temperature levels;
- 2 soil types (sand and silt);
- 2 airflow rates;
- 4 rinsate application methods;
- 4 run times for the system.

All possible combinations of these 5 factors were tested. Two common chemicals (atrazine and fluometuron) were used to “make” the rinsate. The chemicals were mixed with water to create a 20-ppm (parts per million) solution. This concentration was chosen because it would be very similar to the chemical concentration found in most rinsate. Evaporation was tracked and chemical degradation was checked with soil sampling techniques during testing for each environmental condition.

The results of the testing were very encouraging. Significant amounts of rinsate evaporation and chemical degradation were recorded in all tests. Soil type was determined to be one of the most important factors for both evaporation and degradation. The sandy soil exhibited higher evaporation rates. Evaporation was about 10% higher for the sandy columns than for the silt filled columns. However, the silty soil experienced a much greater degradation rate than the sand. Degradation was 85% for atrazine (of the total added) and 59% for fluometuron. Although evaporation for the silt was slightly lower than for the sand, the significantly higher degradation rates pointed to a silty soil as a better choice for soil bed systems. Evaporation rates for the silt filled columns was 76 gal/ft^2 for the low temperature tests and 176 gal/ft^2 for the high temperature tests over a 180-day period. These evaporation rates were still sufficiently high enough to meet the need for volume reduction.

Chemical concentrations in the soil columns increased over time with continual loading, but did not pose a problem to the degradation efficiency of the system. As concentrations in the columns increased, the average percent chemical degradation in the columns also increased. This was an indication that the columns would not become overloaded and could continue operating indefinitely.

The time of flooding and drying in the columns was varied between 5 and 10 days to determine the optimum ratio of aerobic/anaerobic conditions. The optimum cycle duration was found to be 5 days. This 5-day cycle consisted of 5 days of flooding followed by 5 days of drying in the column. This sequence was then repeated for the duration of the test. The 10-day cycle provided the best degradation, but the 5-day cycle resulted in greater evaporation amounts. Also, the 10-day cycle allowed too much drying time, which caused cracks to develop in the soil column. This was a problem, since these cracks provided a direct route for rinsate evaporation during the next flood cycle, which greatly reduced the filtering effect of the soil. Overall, the 5-day cycle produced the most balanced result.

Corwin determined that elevated temperature was more important than airflow. The high airflow did increase evaporation totals, but did not have much of an effect on degradation. The higher temperature tests not only produced higher evaporation rates but also increased degradation rates.

Overall, climatic and environmental conditions play a very important role in the action of a soil based degradation system. The results of Corwin's optimization experiment can be summarized as follows:

- elevated temperature is best for both degradation and evaporation;
- soil type was very important with the silty soils performing the best;
- airflow affected evaporation but overall was not deemed an important factor;
- the 5-day cycle was the best application method;
- run times were indefinite since the longer the system operated the more evaporation and degradation occurred with no significant impact on the soil column.

Yoder's and Corwin's research supported previous research performed on soil based rinsate treatment systems. Corwin's experiment confirmed that this technology, though simple, is quite effective in the disposal of pesticide wastes. He also stated that the technology he investigated could easily be transferred to a full-scale disposal facility.

Glover's Experiment

Taking into account the recommendations in Corwin's research, Scott Glover in 1998 began investigating the possibility of a full-scale disposal system that integrated the technology developed by Corwin (Glover, 1998). Glover outlined 4 specific goals for his project:

- Verify the expected correlation between Corwin's lab-scale system and a full-scale soil bed system;

- Design and build a full-scale control mechanism to automatically operate rinsate delivery to the soil bed based on Corwin's optimization of cycle times;
- Observe performance of full-scale design; and
- Collect information to aid in the development of a full-scale rinsate disposal facility.

Glover's first step was to design a full-scale soil bed. Emphasis was placed on strength, size, and economy. The structural integrity of any soil bed that will contain potentially hazardous wastes is important for several reasons. As discussed earlier, a failure in such a system could endanger both people and the environment. Additionally, the cost of clean-up operations can be exorbitant.

The dimensions of the bed were also an important design consideration. The columns that Corwin used were about 10 inches deep. It was decided that the full-scale bed could be deeper, but not too deep. If the bed were too deep, evaporation totals would be reduced. The soil bed needed to provide enough soil surface area to maintain the evaporation deemed necessary. Also, because the bed may need to be moved or taken out of service at some point, the bed could not be too large or bulky.

Finally, economy was a consideration in the design of the soil bed. Most growers would not be able to afford an expensive installation.

After searching the available materials, Glover chose to use a standard polyethylene bunk feeder available at most farm supply stores (figure 2). This container met all of the design criteria. The bunk feeder was structurally strong and was constructed of high-density polyethylene, which would resist corrosion. The dimensions of the feed trough also adequately fit the purpose. The inside dimensions of the feeder

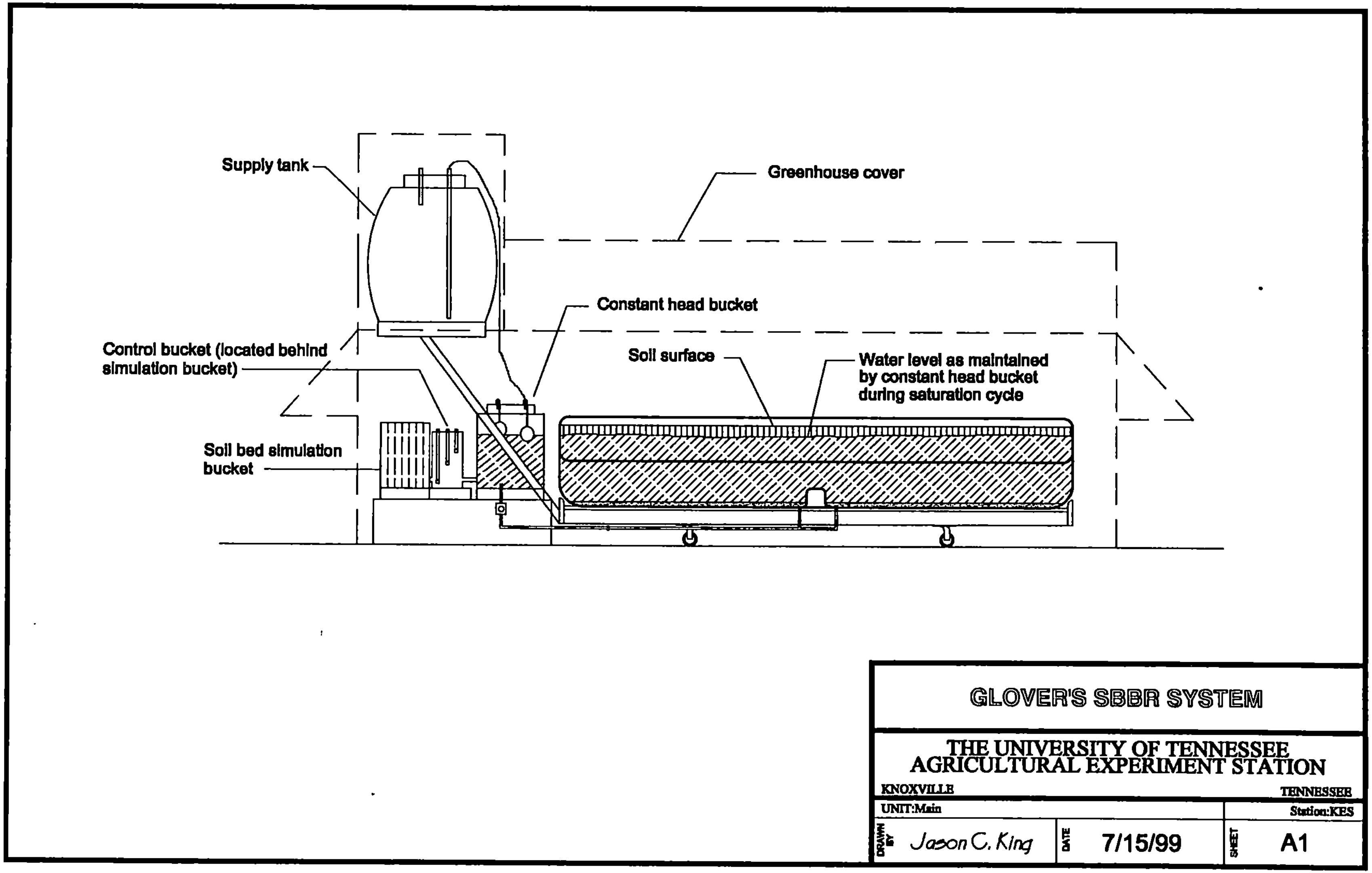


Figure 2. Full-scale soil bed degradation system used by Glover (1998).

measured 9.6 feet by 25.5 inches by 15 inches deep. The 15-inch depth was appropriate for the scale of the project, allowing adequate evaporation as well as increased soil volume. The bunk feeder was small enough to physically handle, and the rectangular shape could easily be fit into any arrangement scheme. This type of bunk feeder was not only inexpensive, but was also readily available to most producers.

Glover's next step was to consider the physical arrangement and set-up of the system (figure 2). Rinsate was supplied to the soil bed through 2 bulkhead fittings placed in the bottom of the soil bed. A frame was designed and fabricated to hold the bed above the ground, which allowed for visual inspection of leaks. Casters were used on the frame to allow for the easy movement of the soil bed. Finally, a greenhouse cover was constructed to fit over the entire soil bed. The purpose of this cover was to increase the temperature in the system. As Corwin noted, elevated temperatures were especially beneficial for chemical degradation.

Having designed the soil bed system, a control device needed to be developed to operate the rinsate delivery cycle. The dual-control system developed by Glover consisted of four parts: a constant head bucket, a control bucket, a soil bed simulation bucket, and two control valves (figure 3).

The constant head bucket was plumbed directly to the rinsate storage tank. Rinsate level in the constant head bucket was controlled by two float valves, one primary and one backup. These valves insured that the bucket would remain filled to the proper elevation. The head provided by the bucket was used to force the rinsate into the soil bed and the control bucket. The constant head bucket was situated such that the elevation of

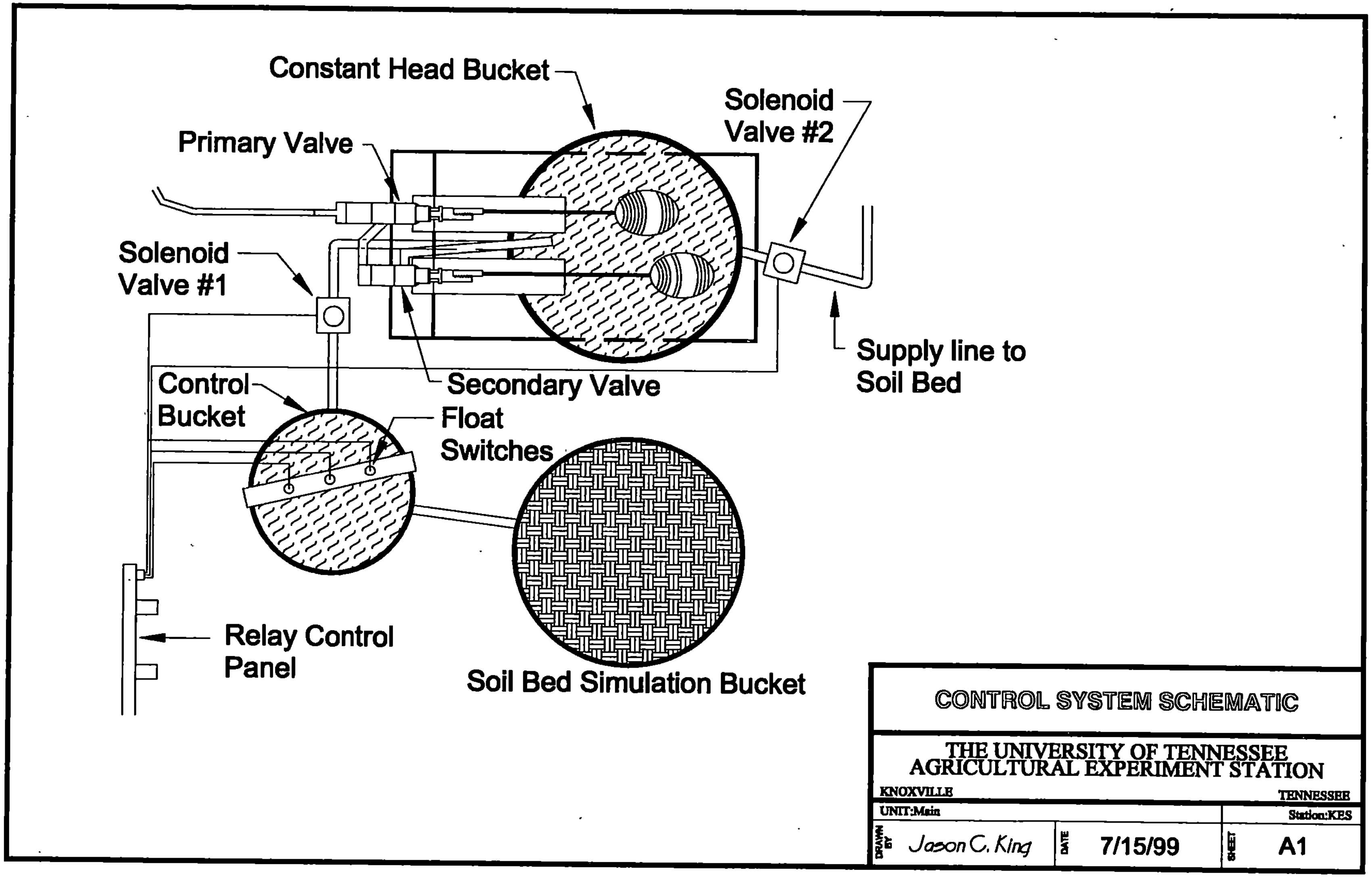


Figure 3. Rinsate delivery control system used by Glover (1998).

the rinsate surface was just below the elevation of the soil surface in the soil bed. This elevation difference prevented possible overflow of the soil bed.

The control bucket and the soil bed simulation bucket worked together to provide an appropriate time cycle for the filling and drying of the soil bed (figures 4 and 5). These two buckets were plumbed together directly with a PVC pipe near the bottom of each container. At the beginning of the cycle the control bucket was filled to its maximum level by the constant head bucket. As water evaporated from the soil simulation bucket, the water level dropped in the control bucket. The falling water level tripped the float switches in the bucket, signaling the filling or drying cycles to begin in the soil bed. After observing the evaporation rate in the soil simulation bucket, the floats inside the control bucket were specifically positioned at certain elevations so that a 5-day filling/drying cycle could be maintained.

The purpose of the soil simulation bucket was to provide a control mechanism with environmental sensitivity. For example, if temperatures were cool for a period of time, evaporation rates would naturally slow in the soil bed. In Glover's system, the soil simulation bucket would also experience reduced evaporation in this case, resulting in a slower water drop in the control bucket. Therefore, this device would cause the entire cycle to slow in response to the environmental conditions.

Two ball valves were used to control the flow of rinsate into the control bucket and the soil bed itself. The action of these valves was controlled by the float switches in the control bucket. A simple relay was used to route the signal from the floats to each valve (figure A1). A marine battery was used to provide power to the system. Glover's tests of the design produced some encouraging results. As in Corwin's tests, a 20-ppm

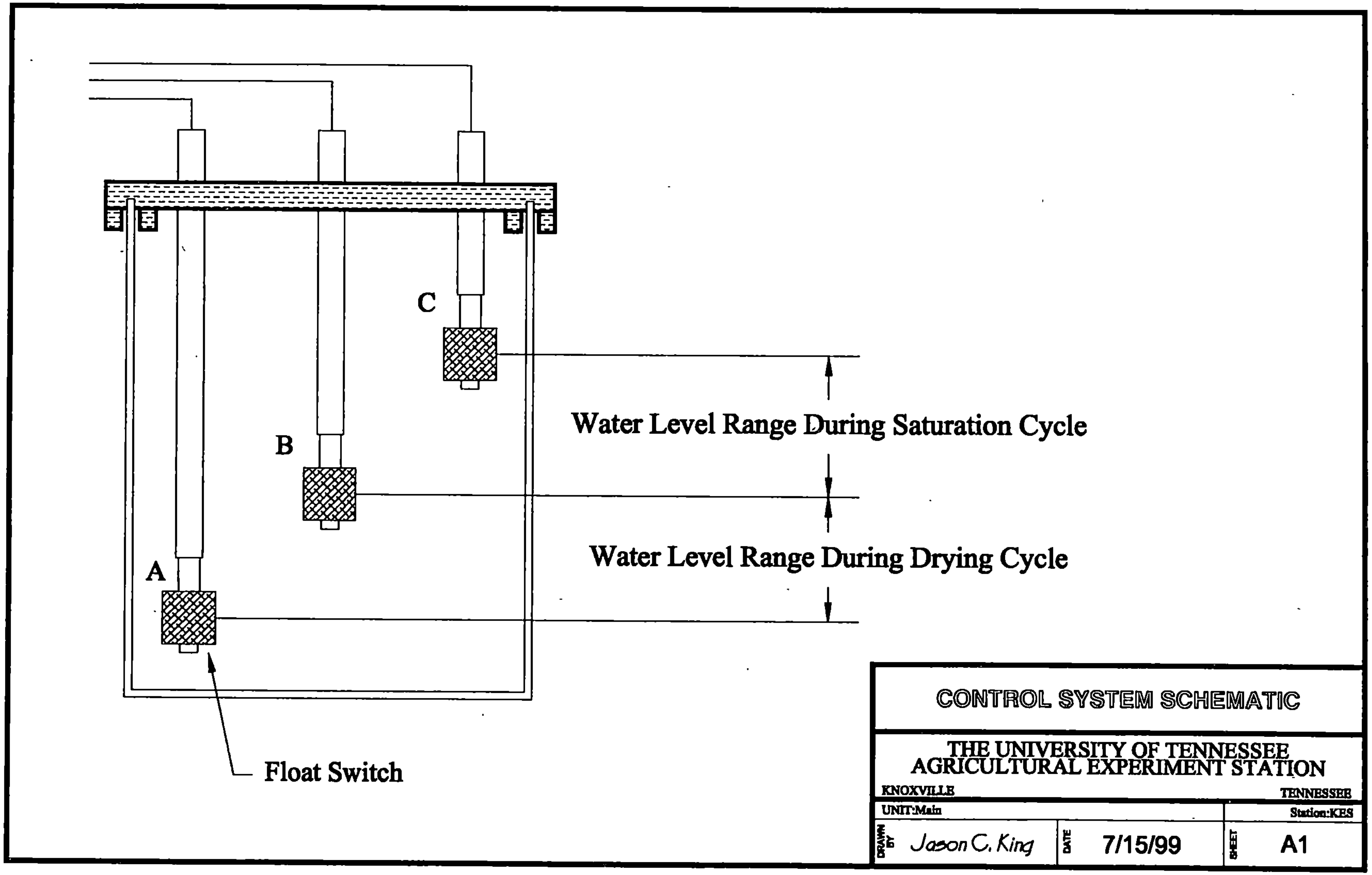


Figure 4. Float switches in control bucket.

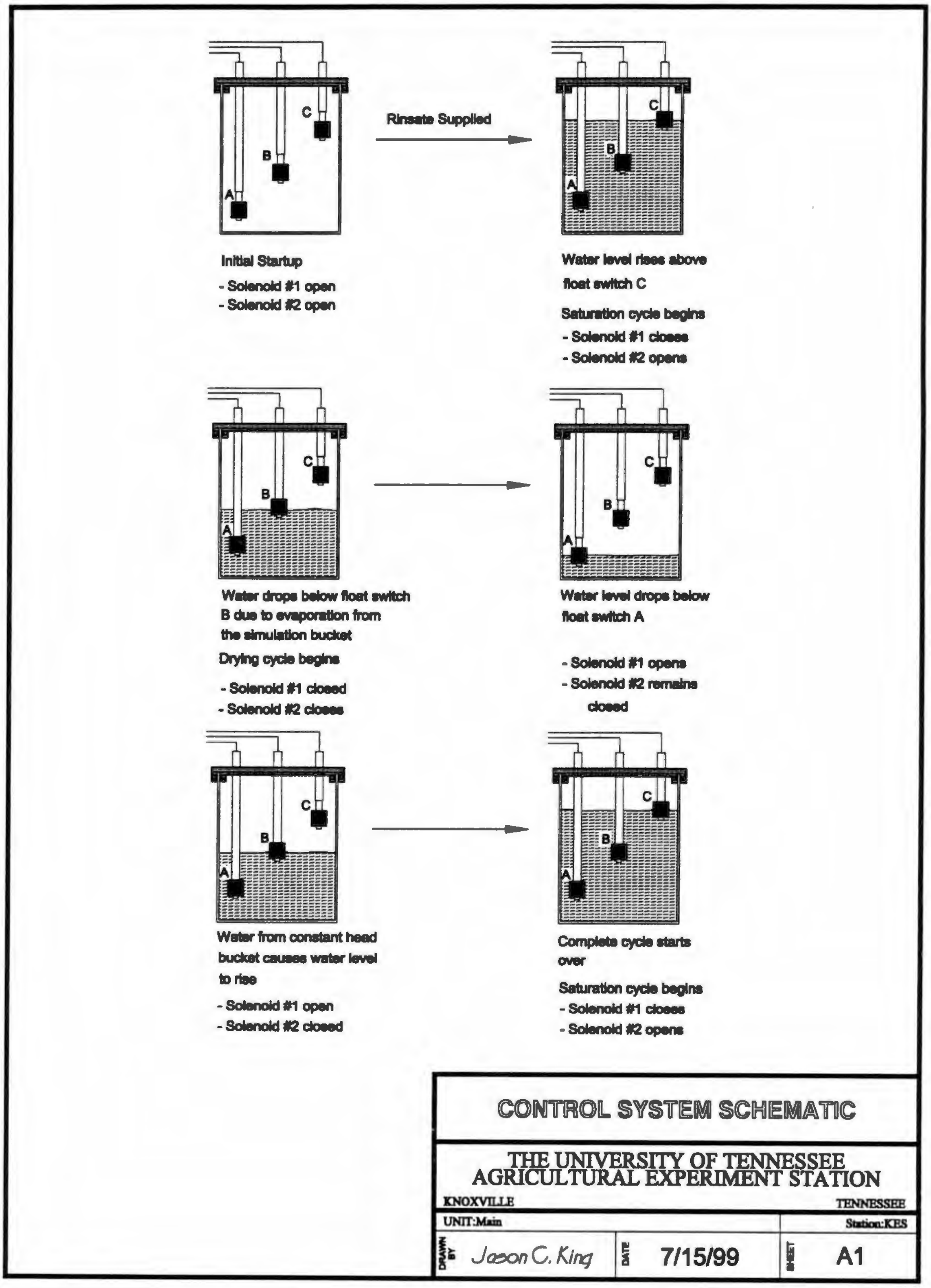


Figure 5. Operation of the floats in the control bucket of the cycle control system.

rinsate solution was continuously supplied to the soil bed. Two pesticides, atrazine and fluometuron, were used to make the solution. A 60-day run time was used for the two tests. The degradation and evaporation totals for the full-scale system were very similar to those found by Corwin. Thirty-five percent degradation was noted for fluometuron, while seventy-three percent of the atrazine degraded. The evaporation over the 60-day test totaled 131 gal. This meant that for the soil surface there was 6.5 gal/ft^2. The control system experienced a few minor problems in the test run, but on the whole worked well. Glover also reported on a number of other factors, including the flow patterns of the two different pesticides within the bed.

Glover concluded from the results of his investigation that a properly built and maintained facility that uses this soil bed technology could be used to safely dispose of pesticide rinsates.

Advantages of Soil Based Treatment Systems

Weighing the options for rinsate disposal, soil degradation beds show the most promise for agricultural producers at the present time. There is no other system currently available that meets the four criteria listed by Dwinell (1992) as comprehensively as the soil bed systems. They are not expensive to build. The cost of operation is very low and the management needed is not complicated. Provided that full containment is provided in the design, they comply with all current regulations. In light of the hazardous waste issue with unknown mixes, soil based systems allow the operator to maintain complete control over what chemicals are used in the system. Finally, these systems are an effective means of disposing of pesticide rinsate.

CHAPTER 3

DESIGN CONCEPTS

The design concept for this pesticide-handling facility consists of three distinct parts: a rinsepad, a greenhouse enclosure, and a full scale SBBR system. The purpose of the rinsepad is to contain and collect pesticide rinsates and deliver them to the disposal system. A greenhouse enclosure will be designed to house the disposal system. This type of structure will allow a greater amount of control over environmental conditions, such as temperature, than is possible with most other building types. The SBBR system design is based on the full-scale system developed by Glover (1998).

Rinsepad Design

The first part of the facility that must be designed is the rinsepad. It is the most site-sensitive aspect of the facility. There are two important reasons that the siting of the rinsepad is so critical. First, the possibility of an accident is greater at the rinsepad than at the rinsate disposal area, since full strength chemicals will be routinely mixed and loaded there. Because the accident potential is considerable, great care must be taken in choosing a location, including consideration of both human and environmental factors. Second, the rinsepad must be built in a convenient location so that it can be effectively used by farm personnel. It must also be located in close proximity to the pesticide storage area so that the possibility of a spill during transport can be reduced. Once the rinsepad site is chosen and a design is completed, the disposal elements of the facility can be planned in response to the rinsepad.

Site

In most cases the selection of a site for a rinsepad is fairly simple because the options are limited. Due to space limitations, a grower may not have many open areas on which a rinsepad can be built without sacrificing crop or pasture area. Also, most growers would like to locate their rinsepad such that it is convenient to other preexisting farm structures, such as a shop or storage building. The geology and topography of the farm may also limit the number of acceptable building locations.

This facility will be built at the Plant Science Unit of the Knoxville Experiment Station in Knoxville, TN. Currently the station has an adequate pesticide storage facility. In many cases, existing facilities can be modified to meet the design requirements of a rinsepad. Unfortunately, the storage space at the Plant Science Unit is located within a larger building that cannot be easily modified. Therefore, a new rinsepad needs to be located as close as possible to the storage area. Since chemicals will be carried by hand to the rinsepad for mixing and loading, the closer the two buildings are, the less likely it is that accidental spills will occur. Fortunately, the area directly across the gravel drive from the current storage building is not in use at present (figure 6). Logically, this is the best location for the rinsepad.

However, just because the site is convenient and available does not mean it is acceptable for this type of facility. In the Tennessee Valley Authority's <u>Manual for</u>

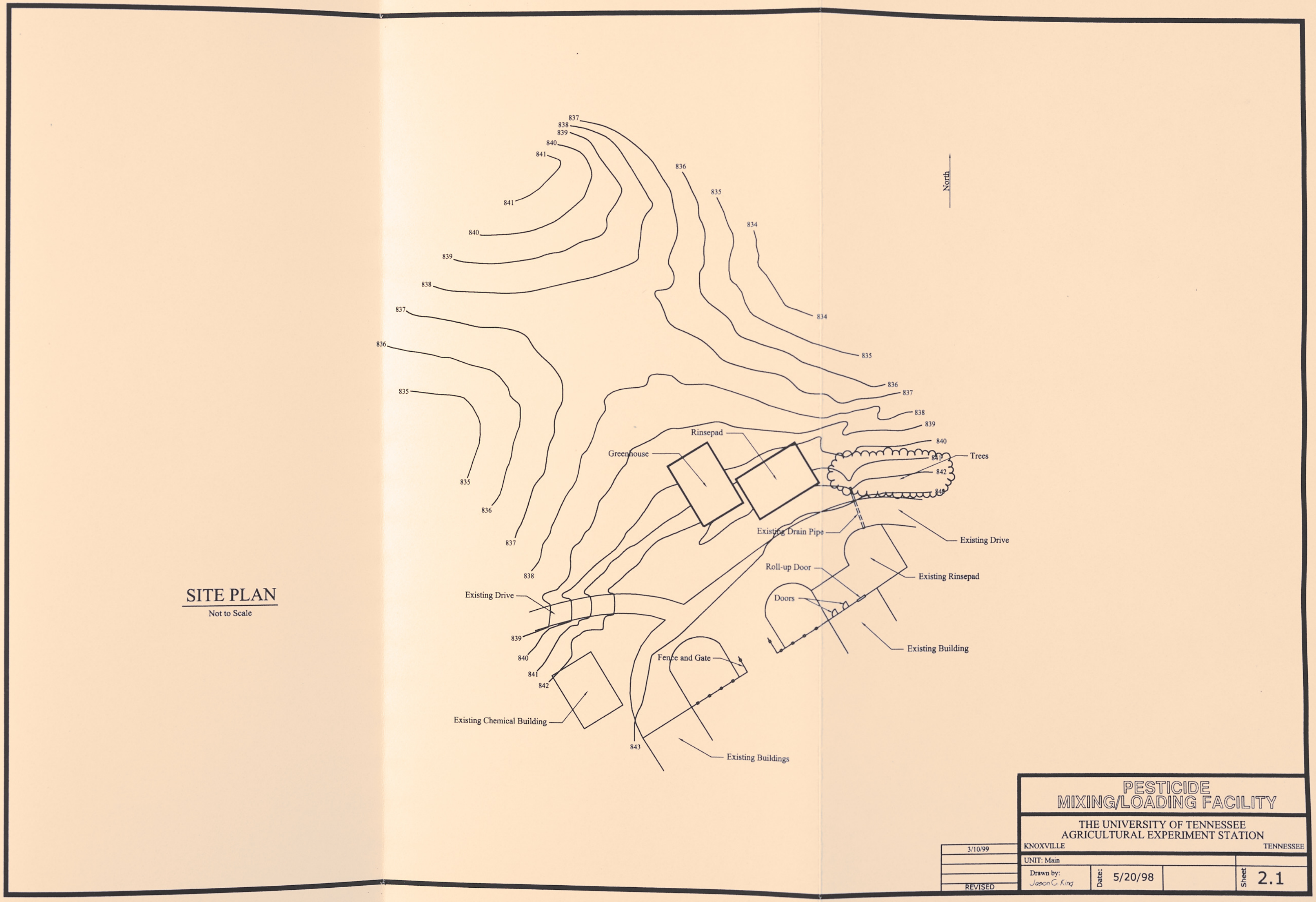


Figure 6. Site plan for rinsepad and disposal facility.

Pesticide Containment, Tate et al. (1990) note that there are 5 criteria which must be evaluated when selecting a new site for a mixing/loading facility. They are as follows:

- prior use of the site;
- site geology and soil;
- site topography;
- proximity of the site to vulnerable structures or environmental elements; and
- permits required and or state regulations with regard to the site selected.

Prior Use

Prior uses of the site selected are important for a number of reasons. An example would be a site that is contaminated before the construction of a rinsepad. If at some point in the future there is a leak in the pad and an investigation is made to determine the source and extent of the problem, it will be impossible to determine what contamination was caused by the leak and what already existed before the rinsepad was built.

The site chosen has had two different uses in the past. The central portion of the site located on a small saddle has been used for the planting of experimental plots, but for the past 10 years it has not been used for this purpose. At present, it is maintained as a grassy area. The other portion of the site consists of the gentle slope stretching from the shoulder of the gravel driveway down to the saddle. This area has never had any specific use. There is some concern that trace amounts of pesticides may be present on the site. Its prior use as an experimental plot as well as its close proximity to the present pesticide mixing, loading, and storage area suggest that this may be the case. In order to reduce the station's liability, soil samples will be taken when the site is graded and when the footers are dug. The soil samples will be analyzed to determine the extent of any contamination. The results of these tests will be analyzed and kept on record in the event of a problem or question. As long as these soil tests are conducted and the results are carefully recorded, there is nothing about the prior use of the site that would indicate a problem with this location.

Soils and Geology

The geology of the site is the next factor to be considered. According to the USDA Soil Survey for Knox County, TN (1955) the soil type on the site is a Sequoia silty clay loam in the severely eroded stage. Longwell et al. (1963) note that this soil exhibits a very high runoff potential, a very great erosion potential and a slow permeability characteristic. First hand assessments of the site have confirmed this analysis. For a rinsepad facility these soil characteristics are ideal. In a situation where waste containment is a goal, as it is in a rinsepad, a soil with low permeability will help to reduce the risk of contaminant movement into the ground.

There is not a shallow water table anywhere near this location. The site itself is situated on top of a small hill and is well drained. Recently an irrigation system has been installed on the entire experiment station. One of the water lines was placed approximately 100 feet downslope from the proposed rinsepad site (Sarten, 1999). During construction of this line no water or gray mottled soil were encountered, even at this lower elevation. These observations were taken as an indication that the water table is not close enough to the surface to present a problem for the placement of the rinsepad.

Though East Tennessee is known to be an area with extensive Karst geology, there is no evidence that this exists anywhere near the proposed rinsepad site. There is no sign of sinkholes or other similar features. Also, during construction of the irrigation system, the bedrock material under the experiment station was found to be shale, not limestone.

Frost heaving is not a significant issue with this soil type, but it does exhibit a significant amount of shrinking and swelling upon wetting and drying. The station superintendent has noticed this problem in the existing chemical storage area which is located about 50 feet from the proposed rinsepad site. This soil characteristic must be seriously addressed in the design of the concrete pad.

Topography

An extensive survey of the site was made in order to better analyze the topography of the location. One of the primary purposes for this map was to develop a detailed contour map of the site. As mentioned earlier, the site chosen is located along a gravel drive behind the current pesticide storage facility. The land slopes away on three sides of the proposed site. Therefore, runoff will naturally move away from the sides and rear of the building. The rinsepad will be just slightly below the road level so some runoff will move toward the front of the rinsepad. This runoff pattern will be modified with fill soil such that storm water will move to the sides of the building and down the hill. The site is not located anywhere near a 100-year flood plain, so the possibility of flooding is extremely small.

Proximity

Another purpose for the survey was to locate all the buildings and natural features near the site. It is important to note the locations of these structures so the rinsepad can be located a safe distance from them. Kammel (MWPS, 1991) lists a number of minimum setback guidelines. They can be defined as follows:

- 100-ft setback from surface water such as rivers or lakes, wells, or drainage ways;
- 200-ft setback from populated buildings either business or private;
- 50-ft setback from any underground fuel storage tanks;
- an acceptable distance from water table or flood plain depending on geology; and
- 50-ft setback from surrounding buildings except other pesticide storage areas.

One very important feature to stay away from when choosing a building site for a rinsepad is wells. Unfortunately, wells and well casings can be a direct path for contaminants to ground water. Most designers suggest staying at least 100 ft away from current or abandoned wells (MWPS, 1991; Waskom and Yergert, 1994; Harris et al., 1997). The Plant Science Unit is connected to the Knoxville city water system, so there are no wells within 100 ft of the proposed site. Also, there are no creeks or surface water within 200 ft of the site. As discussed earlier there is an acceptable distance to the water table from the site surface.

The site is not located in close proximity to any other businesses or residential areas. The nearest populated building is a house used by the experiment station personnel. According to the USGS quad sheet (Knoxville quadrangle) (1977), the house is about 600 ft away from the proposed rinsepad location. The nearest residence that is not on the experiment station is about 800 ft from the site.

The nearest building to the site is the current pesticide storage area. It sets about 50 ft across the road from the rinsepad location. This storage area is a part of a larger building that includes a shop and an equipment storage area. The chemical storage portion of the facility will be the only section of this building within 50 ft of the rinsepad. Additionally, there are no underground fuel storage tanks within 50 ft of the proposed site.

Regulations/Permits

Waskom and Yergert (1994) note that in some states there are codes or regulations governing the selection of a site for a rinsepad facility. The state of Tennessee does not currently have any rules governing the siting of mixing/loading facilities.

Design

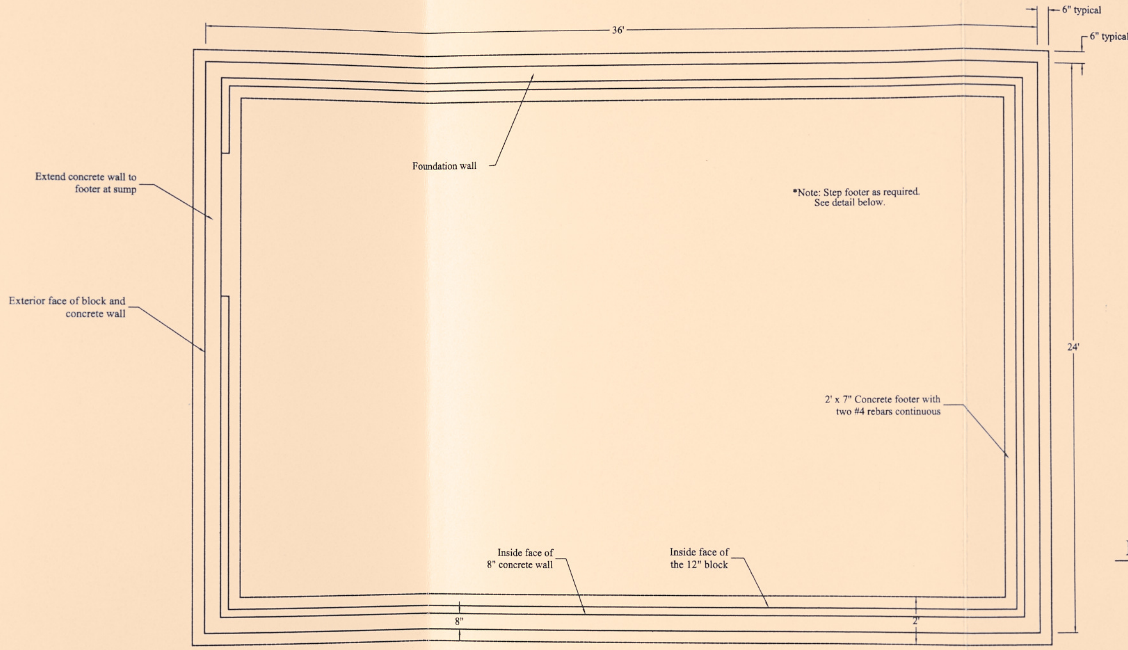
Once the site for the rinsepad has been selected, a design can be developed to meet the needs of the farm. There are many elements of a successful rinsepad design. All of these parts must work together to provide a secure area for collecting and storing rinsate or other pesticide wastes.

Foundation

The most basic part of any building is the foundation. Without a proper foundation any structure will develop problems over time. The selection of a foundation type for a rinsepad facility is especially important due to the nature of the materials that will be handled inside. There are two foundation designs used by most rinsepad designers: the traditional footer and the downturned slab. Many designers have suggested the use of a downturned slab foundation for rinsepads (MWPS, 1991; NRAES, 1995; Tate et al., 1990). The problem with this design is its tendency to crack due to settling. This problem is especially noticeable when a downturned slab is used to support a structure of some type. Cracks are unacceptable in this type of facility. Downturned foundations are better suited to rinsepads that do not support a covering structure. Due to the fear of cracking, a traditional footer with poured wall and a floating slab was selected for this rinsepad. The tendency of the soil on the site to shrink and swell also pointed toward the use of a regular footer system.

The dimensions for the footer itself are 7 inches high by 2 feet wide (figures 7 and 8). The footer runs continuously around the perimeter of the structure. Two #4 steel reinforcing bars (rebar) will be cast in the footer for reinforcement. Due to elevation differences on the site it may be necessary to step the footer in order to provide a firm foundation. In this case the rebar would be tied together as show in (figure 7).

Footer drains will also run around the perimeter of the building to drain excess water from the footer area. This will help reduce the shrinking and swelling tendencies of the soil. There will be one drain on either side of the footer wall. Each drain will rest



FOUNDATION PLAN

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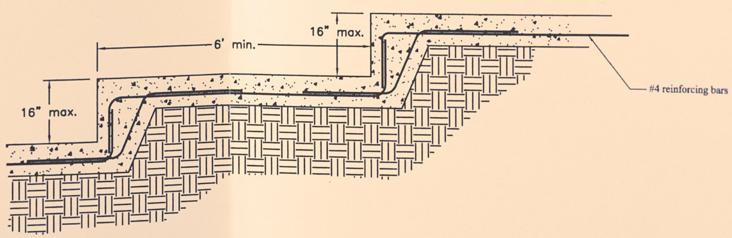

TYPICAL STEP FOOTER DETAIL

Not to Scale

PESTICIDE MIXING/LOADING FACILITY

THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION

3/10/99	KNOXVILLE	TENNESSEE
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Figure 7. Foundation plan for the rinsepad.

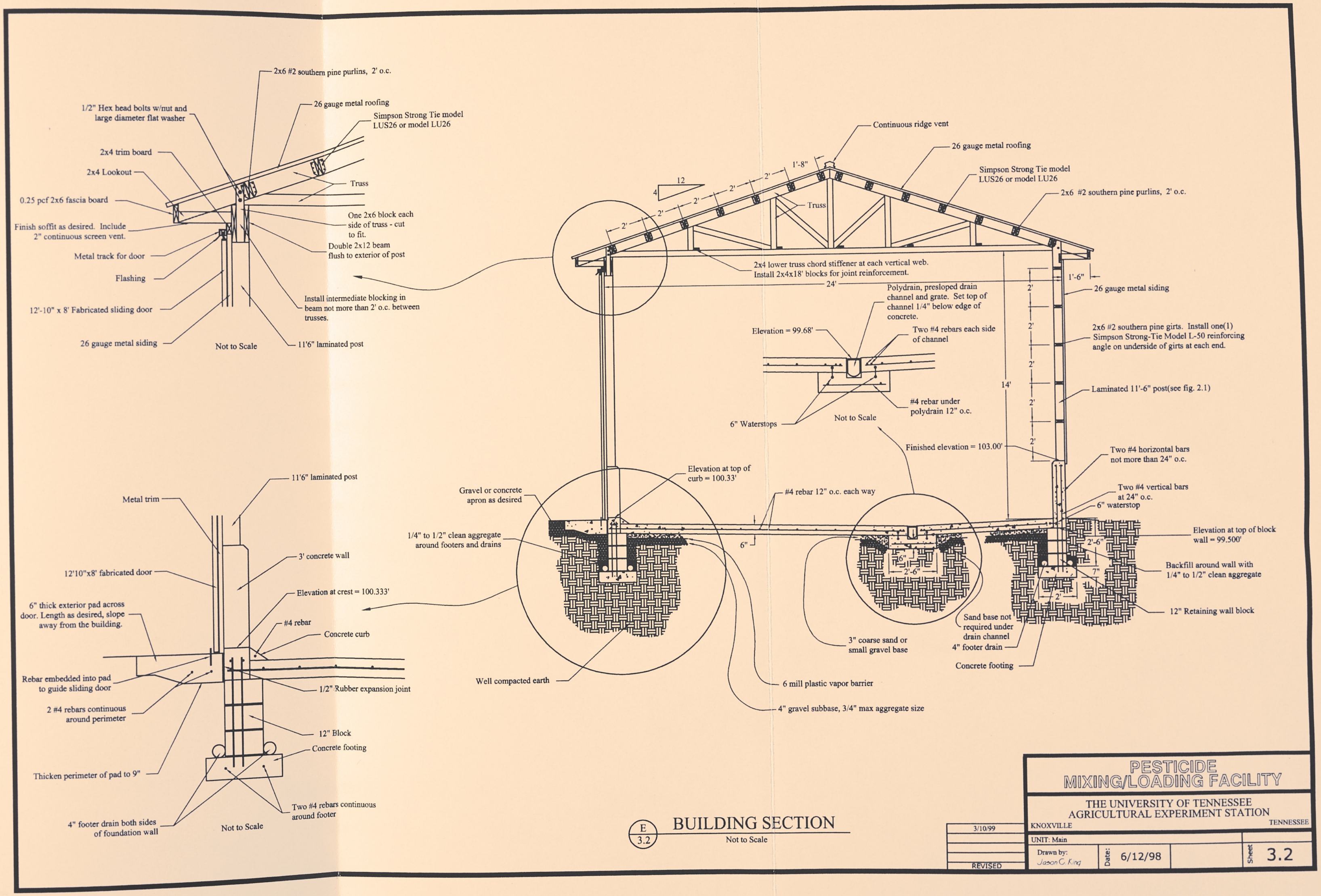

Figure 8. Building section for the rinsepad structure.

on top of the footer. The outlet for the drains will be at the lowest corner of the foundation. If the footer is stepped, it may be necessary to have more than one drain outlet. This decision will depend on the elevation and direction of the steps. Backfill material around the footer drains is specified as ¼-inch to ½-inch clean aggregate so that the drainpipe holes will not clog.

The footer wall will be made of a combination of concrete and retaining wall block. This block wall will be built on top of the poured footer. After the block has been laid, it will be filled with concrete. This construction method eliminates the need for forms in pouring the foundation wall. The rinsepad will incorporate a sump to collect rinse water. The block wall system will not be used behind the sump due to concerns about the possibility of leakage. At this location, a form will be built and the wall will be poured. Rebar will be placed inside the block and concrete wall to provide reinforcement. Two #4 bars will be placed vertically at 24 inches on center (o.c.) into the footer as it is poured. Therefore, the block wall will be built by placing the block down over top of the standing rebar.

With special consideration given to the type of structure and the soil conditions on the site, this foundation design will provide the rinsepad a strong base to rest on.

Concrete

Concrete takes on a special importance in a mixing/loading facility. It becomes the principle barrier between spills or rinsate and the environment. Therefore, the specifications for the concrete mixture need to be carefully considered.

Veenhuizen and Ozkan (1993) note that the qualities looked for in concrete for general construction are not necessarily the same ones desired in a rinsepad. Strength and workability are two important traits that are generally desired in concrete, but for a facility where corrosive chemicals are going to be dealt with durability is essential. Cement quality can greatly affect the durability of the concrete since it is often in direct contact with the chemicals. Rinsepads without the proper cement will tend to develop cracks or flakes on the surface that can eventually lead to continuous cracks all the way through the pad. Therefore in this case, durability will be a major concern. Another important concrete quality is watertightness. A nonporous aggregate as well as a high quality portland cement paste are essential to a watertight concrete pad. The water content should be limited in the concrete mixture since concrete with a large amount of moisture is not as strong and tends to shrink and crack upon drying.

Kammel (MWPS, 1991) includes a list of the important factors that need to be specified in a concrete order for this type of facility. They include the following:

- Type I or II Portland cement
- 4000 psi minimum 28-day compressive strength
- 0.40 to 0.45 water-cement ratio
- 2- to 4-inch slump
- A water reducing agent or plasticizer
- No additional water added to mix
- 1-inch maximum aggregate size
- Minimize vibration during placement

Once the concrete has been specified the site must be prepared for concrete pouring. The subbase for the pad in this case will be 4 inches of gravel (maximum aggregate size of ¾-inch). On top of that gravel will be a 6-mil plastic vapor barrier (figure 8). The purpose of the vapor barrier is to prevent the movement of moisture from the soil up into the concrete pad (MWPS, 1991). Moisture itself is not necessarily a problem, but it can be an issue when the concrete pad is to be sealed with a sealant. If water moves up into the concrete and then becomes trapped in the pad, it can eventually cause problems with the sealant itself. A properly installed vapor barrier can help prevent this type of problem. Vapor barriers must not be placed directly under a concrete pad because they can cause drying problems during the curing process. Therefore, a 3-inch layer of sand will be placed on top of the vapor barrier before the pad is poured. The sand and vapor barrier will not be placed under the drain system.

The concrete will be reinforced with #4 rebar the same as with the footer and foundation wall. In the pad floor, rebar will be located at 1-ft o.c. in both directions. Reinforcing bars will also be placed in the concrete walls as specified in the plans (figure 8).

Once the concrete has cured, control joints will be cut to help prevent unwanted cracking. Joint depth will be no less than ¼ of the pad thickness and no greater than 30 inches o.c. in both directions (MWPS, 1991). These joints will be completely sealed with a corrosion resistant caulk. Since the entire concrete pad cannot all be poured at the same time, waterstops will be used at all cold joints to prevent leakage.

Pad Design

Arguably the most critical consideration in the design of a mixing/loading facility should be given to the scheme of the concrete pad or floor. The pad will be the only part of the design that will be in direct contact with rinsates and spills on a regular basis. The principal functions of the design, containment and concentration of wastes, will be performed by the pad. In most rinsepad designs, these two functions are accomplished by providing a sloped, impervious surface. The impervious surface, which is concrete in this case, will provide the containment. The sloped floor will supply the concentration by channeling wastewater to a central location where it can be transferred to a storage or disposal device.

The size of the pad is determined by the equipment that it will serve. At the Plant and Soil Sciences Unit the widest sprayer boom measured 24 ft in length. In order to have enough room for a sump and a workspace, the width for the facility was set at 36 ft (figure 9). This width provides ample room for the rinsing of the widest sprayer boom as well as a sufficient amount of workspace. The length of the longest sprayer from front to rear was 18 ft. Using this dimension as a guide, the depth for the facility was chosen to be 24 ft. This spacing will allow the entire sprayer and tractor to fit on the pad if necessary. Since the entire tractor will not normally need to be on the pad during rinsing, the 24-foot depth will provide plenty of space for the job.

The arrangement of the pad is also a function of the equipment that will be rinsed on its surface. A principle component of the pad is a drain running the length of the structure. The drain will be made of a series of pre-fabricated sections. These drain sections are pre-formed and can be easily incorporated into the rinsepad floor. The

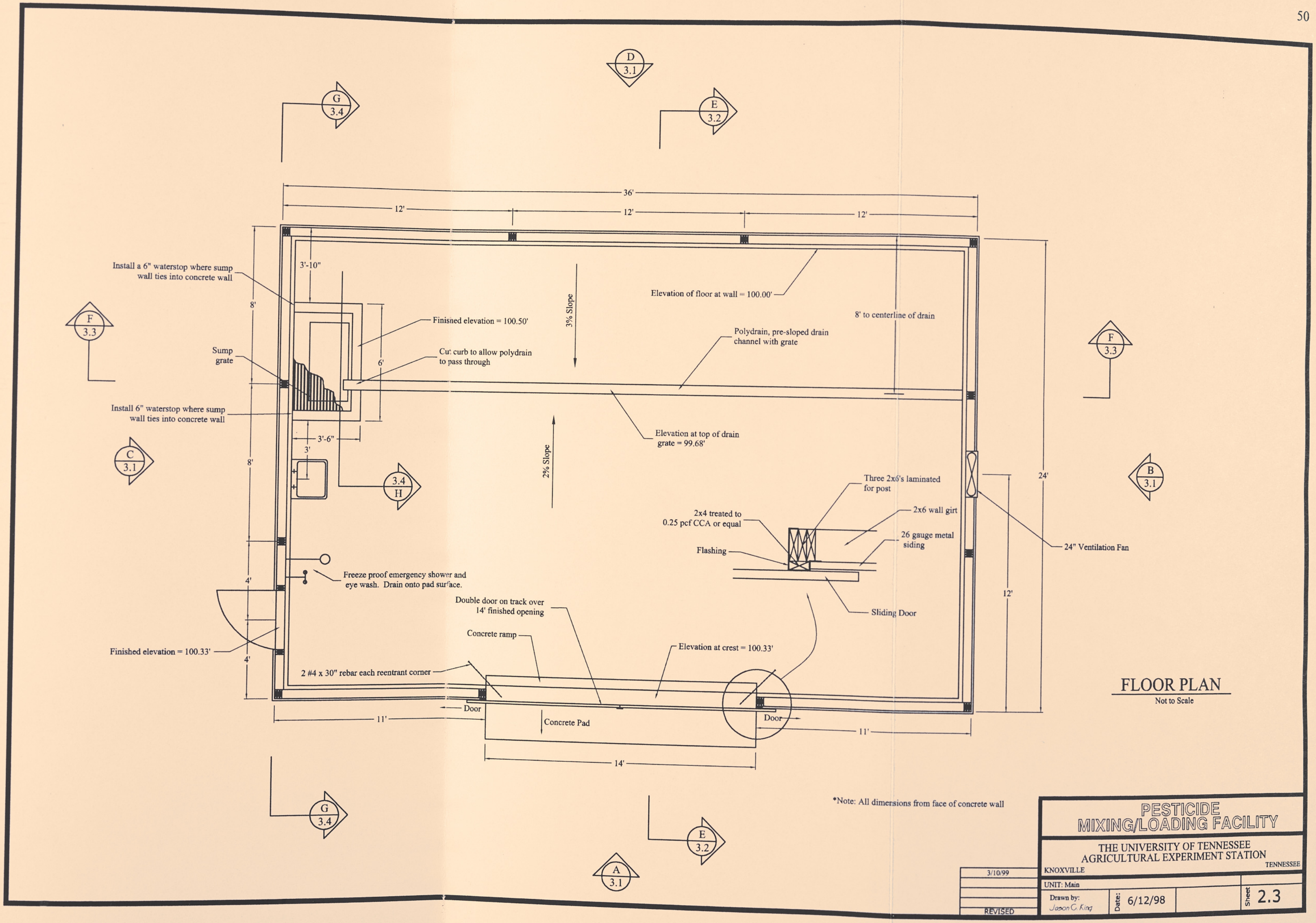

Figure 9. Plan view of the rinsepad.

advantage of this type of drain is that they are pre-sloped. This feature greatly simplifies the construction process because the elevation at the top of each drain section will be the same. As long as the sections are installed in the proper sequence, the slope is built into the drainpipe itself. Additionally, the drain is covered with a metal grate.

The drain will be placed slightly off-center in the pad. In most cases the tractor operator will back the sprayer into the facility until about three-fourths of the equipment's length is on the pad. Therefore, the drain will be placed 16 feet from the entrance of the structure. This will allow the spray nozzles to discharge directly over the drain, reducing the distance wastewater must travel over the pad. The less time wastewater is on the pad, the less likely it is that a contamination problem will occur.

Most rinsepad facility designers suggest a 2 percent floor slope (MWPS, 1991; Grisso et al., 1995; Tate et al., 1990). This slope is small enough to allow easy movement on the pad by people and machinery, but is sufficiently large to move wastewater to the desired location. In this design the pad is sloped to the drain located 8 ft from the back wall of the structure. To simplify construction, the sloped floor surface will meet the foundation wall at the same elevation on both the front and rear of the building. Because the central drain is offset from the center of the floor area, the slope on the backside will be greater than on the front side. The slope will be 3 percent on the backside and 2 percent on the front.

The pad design in this case also includes an 8-inch thick by 3-ft high wall around the facility. The purpose of this wall is to provide additional containment during rinsing. There is generally a good deal of mist created during normal rinsing. A high wall will deflect the biggest portion of this mist and direct it down to the pad floor where it can move safely to the sump. The wall will be cut at the entrance in order to allow equipment to access the facility. At this point, the curb will be only 4 inches high. On the inside of the entrance curb, a small concrete ramp will be placed in order to smooth the drive for the machinery. On the outside of the entrance curb a small concrete apron will be poured (figures 8 and 9). This small pad will serve two purposes. First, it will make a solid connection between the rinsepad and the gravel drive and reduce the chance that the heavy equipment will crack or break the entrance curb. Second, since this small pad will be at a slightly lower elevation than the entrance curb and will be sloped away from the structure, outside water will be directed away from pad.

Another important design feature for the pad is its connection to the foundation wall. As discussed earlier, the soil at the site has exhibits a good deal of shrinking and swelling. To reduce the effects of these actions, the 6-inch thick pad will not be poured directly on top of the foundation wall. Instead the pad will be butted directly up to the foundation with a cold joint. The cold joint will be sealed with a flexible waterstop. This type of connection will allow more flexibility in responding to stresses imposed by the shrinking and swelling of the soil. This will decrease the risk of cracking on the pad itself.

Sump

The sump is essentially an extension of the pad. It is the terminus for the drainpipe and is responsible for the storage of wastewater until it can be transferred for storage or disposal. A sound sump design is also important since it will hold considerable volumes of wastewater during rinsing.

The principal design requirement for the sump is containment. It is especially important to design the sump such that there is a strong secondary containment component. Backup containment is essential in case of a failure of the main sump system.

The primary sump is a simple rectangular container fabricated from ½-inch thick high density polyethylene (figure 10). Polyethylene was chosen for the sump because it is inexpensive, resistant to corrosion, structurally strong, and relatively light. It will be equipped with handles on either end to aid in moving it for cleaning or maintenance. Inside dimensions of the sump are 2 feet by 2 feet by 4 feet. This will provide a storage volume of 120 gallons, but the sump will not be allowed to fill completely. The maximum volume that will be stored in the sump will be 110 gallons.

Water will enter the sump directly from the polydrain. This transfer will be accomplished by extending the final section of drain approximately 3 inches over the sump. The sump bucket will be placed under this overhang in order to catch the wastewater as it exits the sloped drain.

Secondary containment in the sump area will be provided by a shallow concrete pit. In case of an emergency or accident this secondary concrete sump will hold the contents of the main sump until the waste material is removed. The inside dimensions of the concrete sump will be 3 ft wide by 6 ft long by 3 ft 9-3/8 inches deep. The concrete walls in this sump will be 6 inches thick and will be reinforced with #4 rebar as noted on the design drawings (figure 10). All cold joints will be sealed with a flexible waterstop to prevent leaks. In addition to the waterstops, all concrete in the sump will be coated with an appropriate sealant to further insure watertightness. Foundation block will not be used

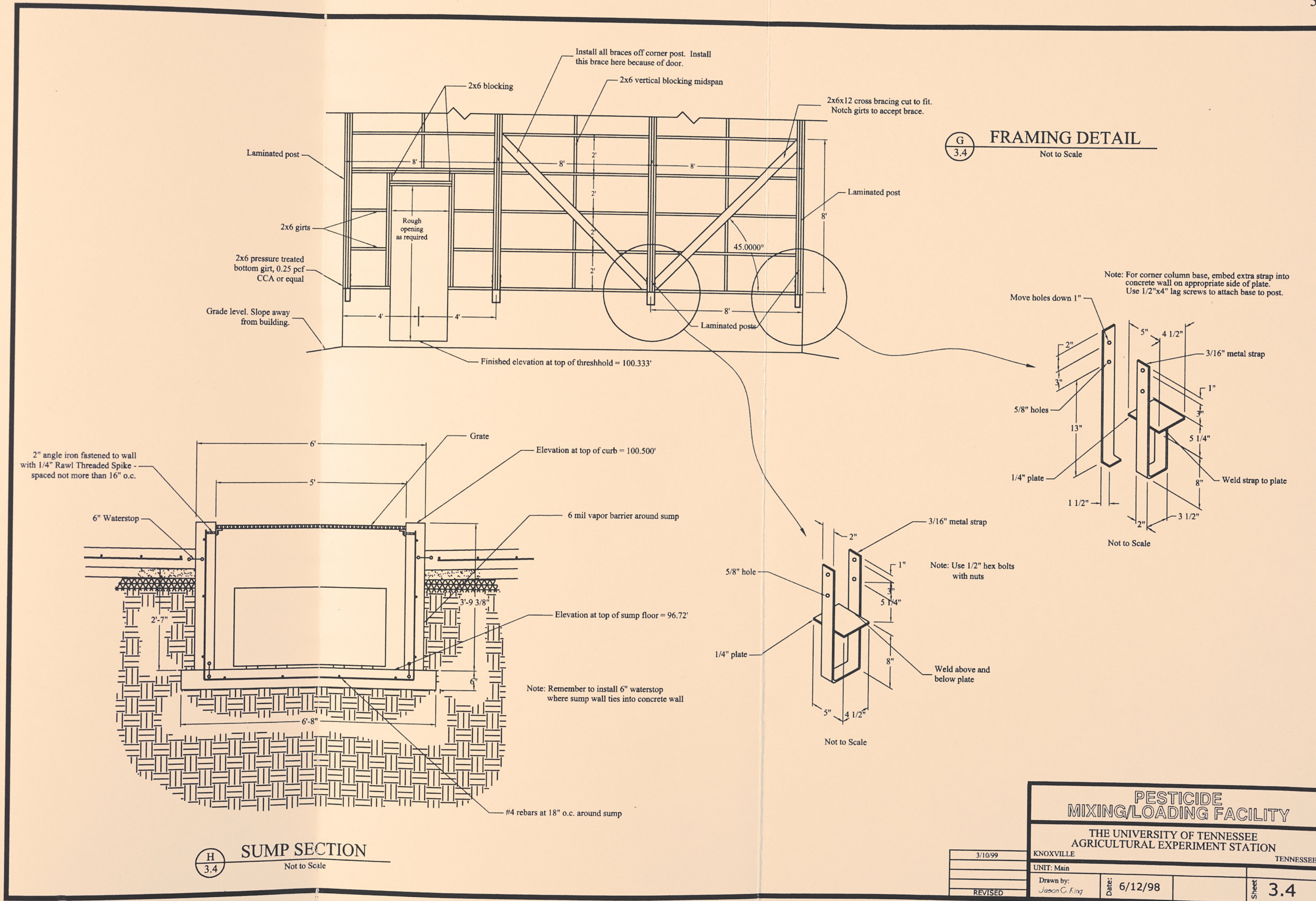

Figure 10. Sump section and framing detail.

around the sump. A 6-inch concrete wall will replace the blocks for the length of the sump. This will allow the sump to be tied directly into the foundation wall. Again, waterstops will be used at this connection. The sump walls extend at least 6 inches higher than the rinsepad floor. This will prevent rinsate from pouring directly into the secondary sump. The curb will direct wastewater around the sump, into the drain, and ultimately into the primary polyethylene sump. The curb will be cut to accommodate the polydrain. A metal grate will be used to cover the sump to prevent individuals from falling into the sump area or throwing foreign objects into it. It will be fabricated or bought to fit the sump opening. The grate will rest on 2-inch angle iron that will be attached to the inside of the sump wall with ¼-inch rawl spikes.

Structural Design

Many rinsepad designs do not include a covering or roof of any kind. Often, they are as simple as a concrete pad and a sump, however, this is not recommended (MWPS, 1991). There are several reasons why this can become a problem. The most obvious problem is rainfall. Even a medium sized thunderstorm can drop hundreds of gallons of water onto the surface of a rinsepad. This amount of water can easily exceed the capacity of the sump. Rainwater collected in the sump may not be clean enough to simply pump out onto the ground. If any pesticide spills or rinsates are not properly cleaned from the rinsepad surface, rainwater will become contaminated as it falls on the pad. This can cause a major disposal problem. Rinsepads without any sidewalls are limited in their ability to contain spray mist that often occurs during rinsing operations. Finally, security can be an issue. When there is not an enclosure around a rinsepad, it can be difficult to limit access only to authorized personnel. Also, due to the experimental nature of this project and the limited capacity of the disposal system, a covering enclosure was deemed necessary for the success of the rinsepad design.

The main structure itself is a simple post and beam type (figures 11 and 12). Treated lumber will be utilized when direct contact with moisture or the outside environment is expected. The main posts will be constructed of three 14-ft nominal 2-inch by 6-inch (2 x 6) boards that will be nail laminated. These posts will be attached to the top of the pad wall using specially fabricated anchor brackets (figure 13). Because laminated posts are to be used, stock brackets were not available to fit the dimensions of the post. Therefore, these brackets will be made by experiment station personnel. The posts will be spaced at 8 ft o.c. on the sidewalls and at 12 ft o.c. on the front and rear walls of the structure.

Girts will be made of 2 x 6 boards and will be placed horizontally at 2 ft o.c. between the wall posts (figures 8, 10, and 12). Girts will run between the posts as opposed to being nailed to the outside of the post. They will be placed on their side so that they will fit flush with the posts on the inside. This will greatly simplify the placement of interior sheathing. Cross bracing will be supplied on each corner section with 12-ft 2 x 6 boards placed at a 45-degree angle (figure 10). The girts will be notched to accept this cross bracing.

Prefabricated trusses will be purchased for the roof assembly with a pitch of 4/12. Four roof trusses will be required in order to achieve a 12-ft spacing. Twelve-foot 2 x 6's will be used for roof purlins. These purlins will be placed between the roof trusses and will be held in place using standard steel hangers. Roofing material will be 26-gauge

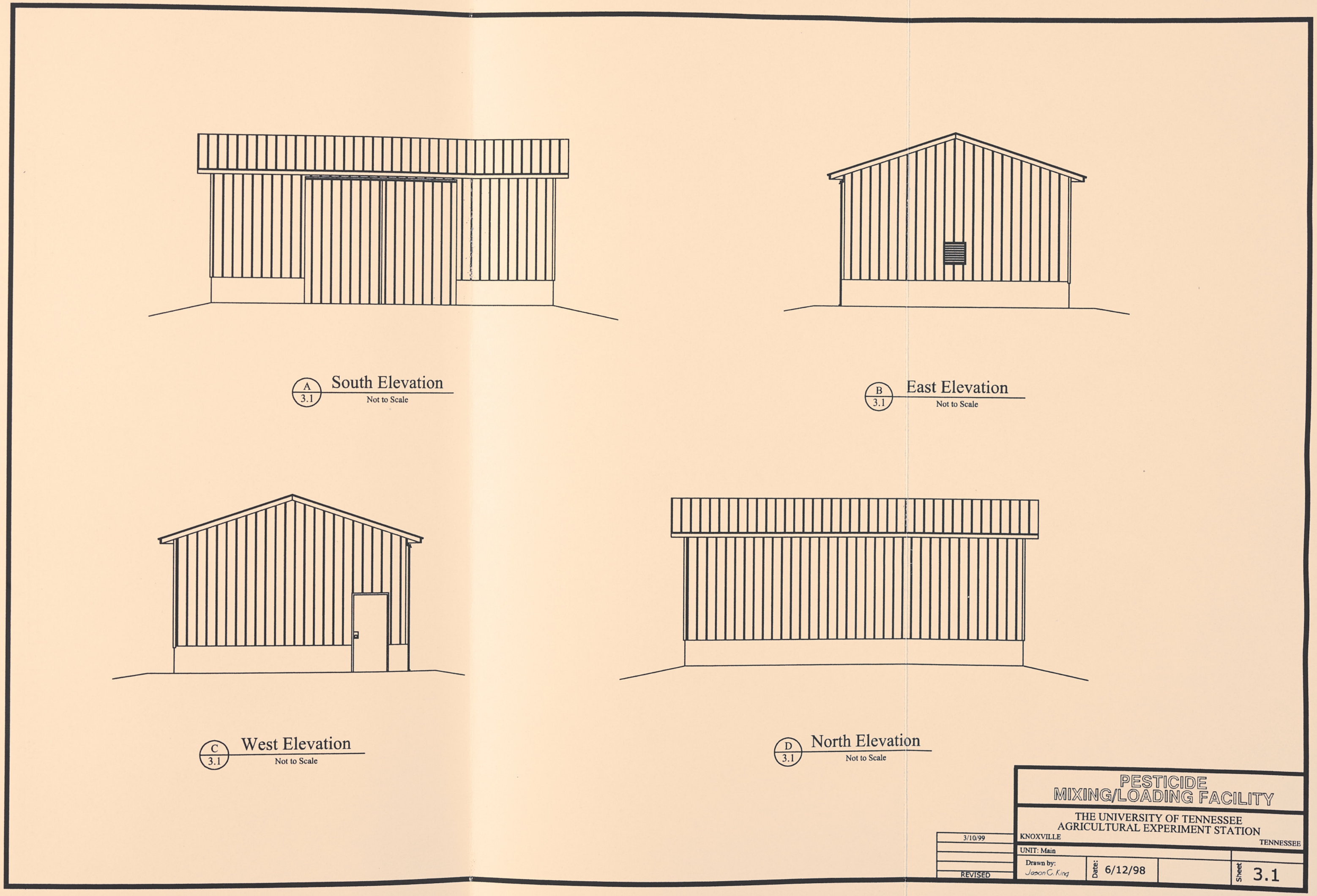

Figure 11. Elevations for the rinsepad facility.

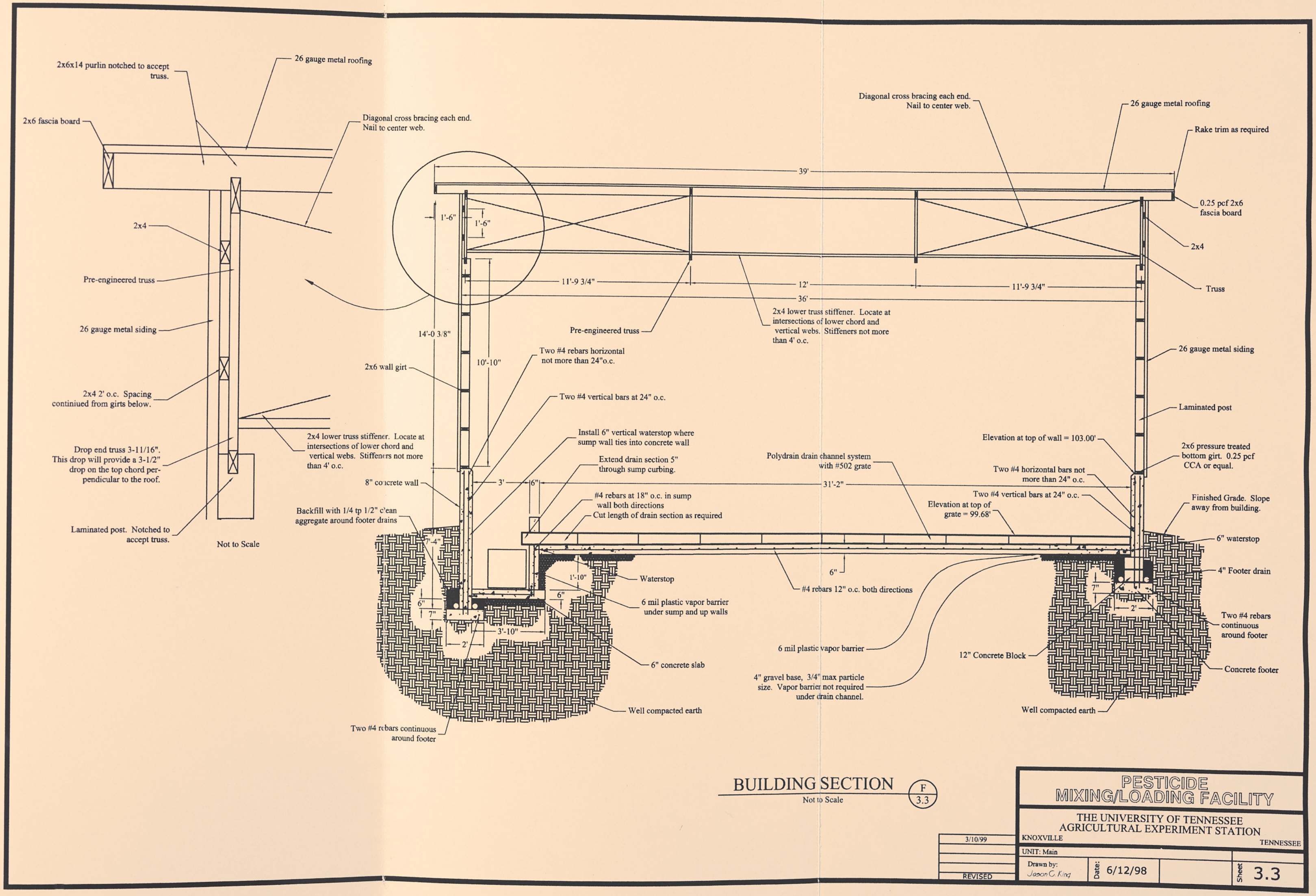

Figure 12. Building section cut through the long axis of the rinsepad.

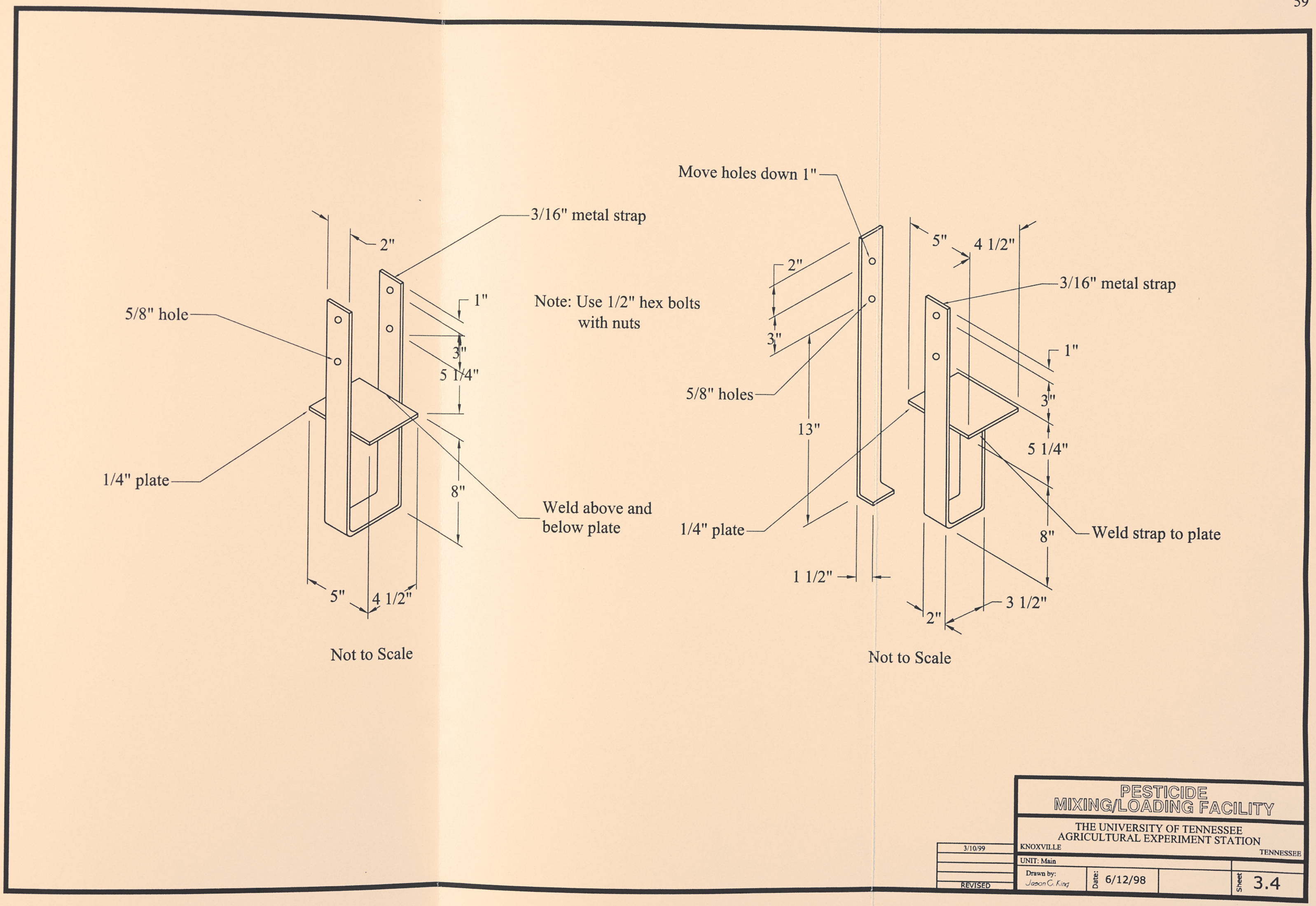

Figure 13. Anchor brackets for laminated posts.

galvanized metal sheeting. The covering for the outside walls of the structure will be also 26-gauge galvanized metal sheeting. An inside covering material will be used to prevent the movement of wastewater in the form of mist or splashes from escaping the building. This material must be non-corrosive and not likely to hold or absorb rinsate. Corrosion resistant fiberglass composite panels will be used for this purpose. The panels will be oriented vertically so the seams between panels will not impede rinsate movement back onto the pad.

Two doors will allow access to the facility. The main door will be a 14-ft wide double sliding door on the front of the rinsepad for equipment entry. Hardware for the door will be purchased but the door itself will be fabricated on site and covered with 26-gauge metal siding. A standard personnel door will be located in the west wall of the rinsepad structure. This door will allow workers to enter and use the rinsepad without having to open the sliding doors for entry. It will also allow access to the disposal facility. Both of these doors will be equipped with locks for security purposes.

Electrical

Electricity will be provided to the rinsepad, since there are several features inside the facility that will require power (ventilation fans, sump pump, lights, etc.). In addition to these items, five or six electrical outlets will be provided for miscellaneous equipment that may be used in the facility. Ground fault interrupters will be necessary at each outlet. Overall, there is a relatively small need for power, therefore, wattage and amperage requirements will be low. Total electrical load for the building will not exceed 15,000 volt-amps.

Since potentially flammable chemicals will be handled in the rinsepad facility, the electrical design must be carefully considered. Recommendations for mixing/loading facilities are covered in the National Electrical Code (NEC) and in the National Fire Protection Association (NFPA) 70. The most critical distinction to be made in the design of the electrical system in this case is the type of chemicals to be handled in the rinsepad. The NFPA recognizes several classes of chemicals depending on their flammability (MWPS, 1991). Class I liquids are those with a flash point below 100° F and are termed "flammable." Class II and III liquids have a flash point of 100° F, or greater, and are considered "combustible." NEC article 500-5 lists two degrees of hazard depending on the class of chemicals to be handled (NEC, 1999). In Class I Division I areas, ignitable mixtures are present on a normal basis. This is the more stringent of the two designations and requires the use of explosion–proof electrical equipment. In Class I division II facilities, ignitable mixtures are only present under unusual circumstances such as an accident. Division II facilities do not require explosion–proof equipment under normal operating conditions.

Kammel (MWPS, 1991) notes that most agricultural chemicals are not considered to be Class I according to the NFPA definitions, thus for most situations explosion-proof equipment is not specified by the code. However, some agricultural chemicals are considered to be Class I liquids so the degree of hazard must be determined. The most important factor to be considered is the amount of Class I material that will be used and how often these materials will be openly exposed inside the facility. According to Kammel (MWPS, 1991), if Class I liquids are handled in such a way that vapors will be sealed inside their containers, mechanical ventilation will be provided to remove any vapor that escapes, and the facility will only become hazardous during an emergency or accident, the facility could be considered as a Division II structure.

Agricultural Experiment Station Engineer Joe Sarten (1999) notes that since a very small amount of Class I chemicals will be used, adequate ventilation will be provided inside the rinsepad, and there will be no chemical storage in the facility, explosion-proof electrical equipment will not be necessary.

Moisture and dust proof fluorescent fixtures will be used to provide the lighting for the facility. Cold weather ballasts will be used to provide a quick start for the lights in cold weather.

An electrical service disconnect will be located outside of the building next to the door in a lockable, NEMA rated cabinet. This will allow easy access to the circuit breaker from the door in case of a problem as well as protect the box from moisture inside the rinsepad structure. All wiring must be elevated above the pad floor. This will eliminate the possibility of submerging the wiring in the event of an overflow.

Plumbing

The final component of the rinsepad design is the plumbing system. There are two basic parts to the plumbing system design: the incoming water supply and the wastewater transfer system from the sump to the storage area.

The primary concern for the clean water supply is to protect the source from contamination. The source of the water in this case is the city of Knoxville water system. A new line will be placed and plumbed into the existing water lines on the site (figure

14). An anti-siphon valve will be used in the incoming conduit to prevent backflow that can result in contamination. It will be located upstream from all other valves in the system. During the winter the rinsepad will not be used on a regular basis. Therefore, a frost-proof hydrant will be placed at the water's entrance to the facility. This will allow the water to be completely shut-off inside the facility. Since there will not be any heating inside the rinsepad, cutting off the water will prevent pipes from freezing.

The water supply will run to the emergency shower and eyewash, the utility sink, and the interior faucet. The sink and faucet will be used primarily for mixing, loading, and rinsing operations. Wastewater from the sink will be piped directly to the sump. Rinsate from the cleaning of spray tanks will collect in the drain and ultimately in the sump. No outlet or drain inside the facility will connect to any outside drainage way or sewer. Standard PVC pipes will be used for the water supply system.

The sump will have a separate plumbing system to deliver wastewater to the disposal area. A submersible pump will be used to transfer the rinsate from the sump to the storage area in the disposal facility. The pump will be placed in the primary sump container. Flexible chemical resistant hose will be used as a conduit for the waste stream. The hose will allow more flexibility for the pump. For example if a spill needed to be cleaned up in another location in the rinsepad, the flexible nature of the hose would allow the pump to be easily removed from the sump and used elsewhere. Also, this design will facilitate the removal of the pump for sump cleaning. Water will be pumped out of the sump and through a vortex type filter mounted on the rinsepad wall (figure 15). This filter will be used to remove solid material (sand and grit) which will inevitably enter into the sump. This filter will help to keep the system clear of clogging problems and to

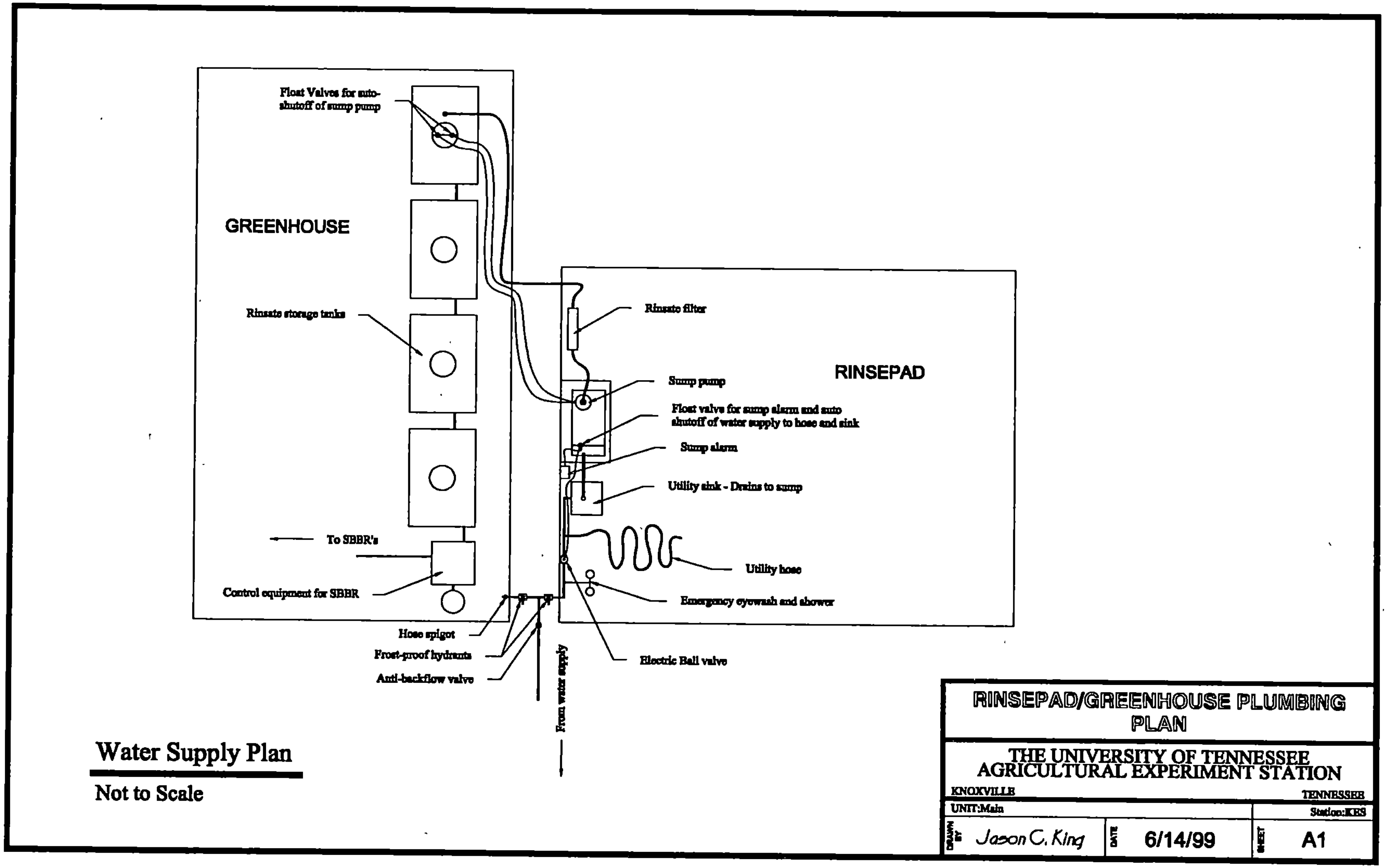

Figure 14. Water supply plan for rinsepad and disposal area.

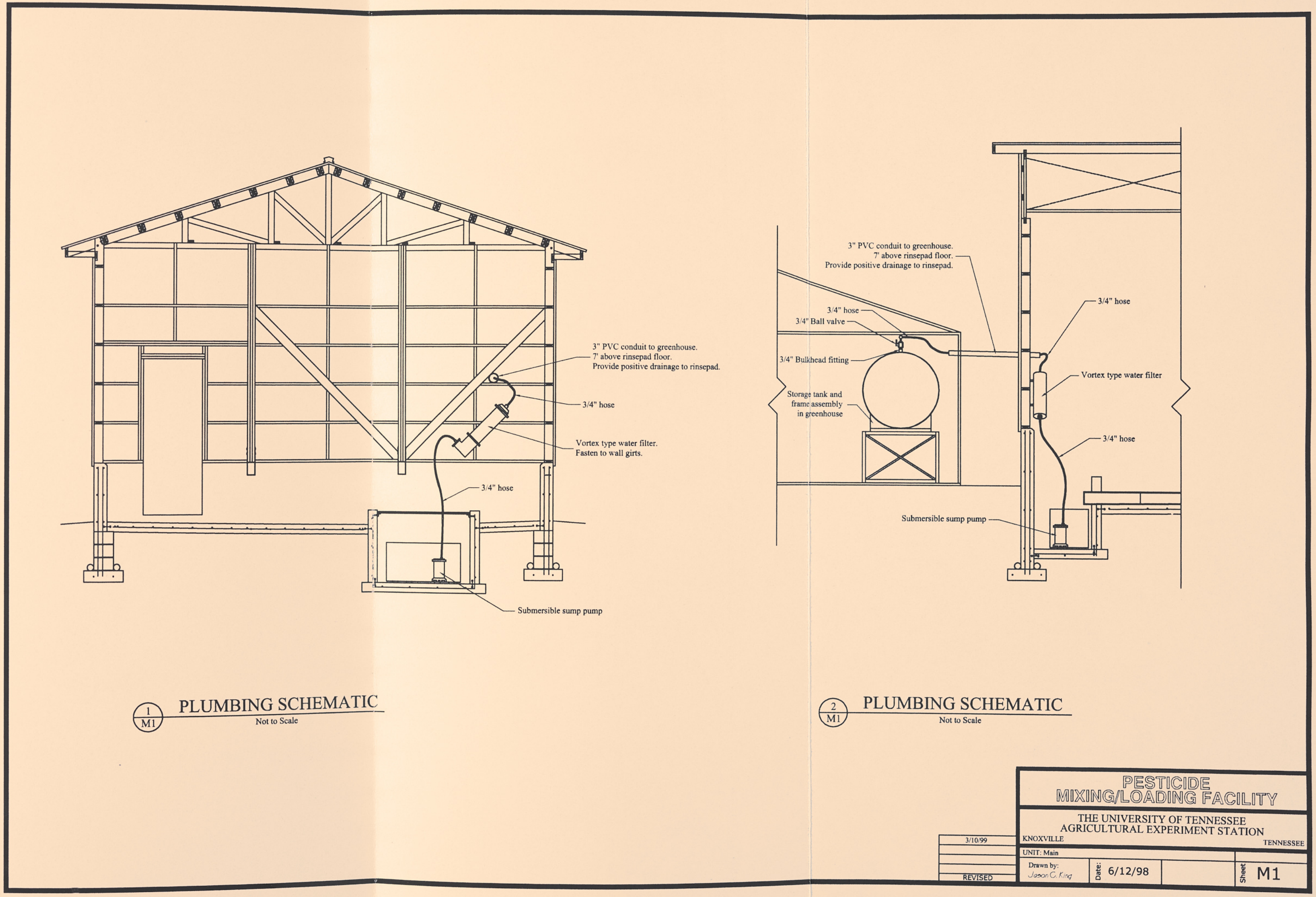

Figure 15. Plumbing plan for sump and rinsate transfer system.

protect the rinsate delivery system (valves, fittings, hoses, etc.) in the disposal area. The filter will have to be cleaned periodically to remove debris that has been cleaned out of the rinsate. This waste will be deposited directly into the soil beds. After the water exits the filter it will move through a flexible hose into the storage tanks in the disposal area.

It is important that complete secondary containment of the wastewater is achieved, so a fabricated double-walled pipe will be used to transfer the waste to the storage tanks. This double-walled system will be accomplished by simply running the flexible hose through a larger PVC pipe between the two buildings. In case of a leak in the hose the PVC pipe will prevent contamination of the site. Positive drainage will be provided to the rinsepad so that a simple visual inspection can be used to insure secondary containment in this area.

Another safety issue to be addressed is the possibility of an overflow of the sump system. In many cases sump pumps can be installed such that they will automatically pump when water is present. However, this solution is not possible in this system for two reasons. The first problem is the possible overflow of the rinsate storage tanks. If the storage tanks are full and the sump pump automatically begins pumping, there will be an overflow problem in the disposal area. Second, the soil bed system is designed to handle dilute wastes such as rinsate. If someone were to spill a container of full-strength chemical on the rinsepad, and the chemical was then automatically pumped into the disposal system, the soil beds could be overwhelmed by this load. Thus, if the sump is not set to run automatically, the operator would be able to contain the spill in the rinsepad area and prevent any problems in the soil bed system.

Ultimately, there is no way to completely prevent a sump overflow other than using extreme care in the operation of the system during normal operation. However, in the case of an accident, an alarm and a water shutoff valve will be used to help prevent accidents from causing a containment problem. The primary sump container will have a float valve that will signal an alarm and a shutoff valve when the sump is full (figure 14). The alarm will alert the operator that rinsate needs to be transferred to the storage area before continued rinsing. An electric ball valve will be used to shut off the water supply to the hose and the sink. This precaution will prevent an overflow of the sump if someone were to accidentally leave the water on in the sink or if the plumbing were to leak. Rinsate in the sump will have to be transferred to the storage area in order to turn the alarm off and reopen the water supply. Overflow prevention in the rinsate storage tanks will be discussed later.

Safety

In any facility where potentially hazardous materials are handled, worker safety issues must be carefully examined. For a rinsepad, these issues can be divided into four primary concerns, ventilation, security, fire safety, and worker protection.

Ventilation

Adequate ventilation is required for any pesticide handling facility. Ross and Bartok (NRAES, 1995) note that proper ventilation removes excess heat, chemical vapors, and moisture from the inside of a rinsepad. For smaller facilities, natural ventilation alone often provides the necessary airflow. In this design natural ventilation was not deemed adequate for the size and scope of the structure. An exhaust fan will be installed in the east end of the rinsepad enclosure to aid in the ventilation process. The fan is located on this end so fumes will be directed away from the disposal facility. The intake air for this fan will be provided by ridge and soffit vents in the building's roof. The fan will pull outside air through these vents to provide the circulation needed. Three to six air changes per hour based on the inside volume of the structure are generally recommended for mixing/loading facilities (Wilkinson, 1997). The rinsepad enclosure has an interior volume of approximately 14,000 cubic feet. In order to provide five air exchanges per hour, an airflow of 1170 cfm will be required from the fan. A medium-duty 24-inch fan will provide the necessary airflow. It will provide 4,500 cfm at 0 inches H_2O and 4,000 cfm at 1/8 inches H_2O. The fan will be located as low as possible on the east wall so that vapors which are heavier than air will be removed from the work area.

The ventilation fan will not be on at all times, since the facility will not be in use every day. Also, since there will be no chemical storage in the rinsepad area, there should not be any vapor buildup. For the safety of the workers, however, a motion sensor will be mounted inside the rinsepad to turn on the ventilation fan whenever movement is detected.

Security

Another safety issue to be examined is security. Unauthorized use of the facility or vandalism could have serious consequences, including personal injury or environmental contamination. Each rinsepad building site is different, so the risk level of the situation must be considered on an individual basis.

The risk of vandalism is fairly low at the Plant Science Unit. The site is not readily available to the general public and two staff members live on the station and will be able keep a watch for trespassers. In the past vandalism has not been a problem at this location.

A more serious concern at this facility is unauthorized use of the facility. A large number of people visit the station daily, including faculty and staff, station personnel, and university students. Curiosity or ignorance could persuade someone to use the facility in an inappropriate manner. In the worst case, a serious spill may occur and not be reported. The best protection from these types of problems will be to keep the facility securely locked when not in use. Since the rinsepad will initially be a research facility, use of the rinsepad will be restricted to those who have been specifically trained in safe usage of the facility. As long as the structure is used only by those who are properly trained, the risk of a problem will be minimal.

Fire Safety

Fire can be a serious hazard in a mixing/loading facility. Since there will not be any chemical storage in the rinsepad area, the risk of fire is greatly reduced, but it is still a concern. This design will adhere to all local fire codes for this type of facility. Smoke detectors and alarms will be installed as soon as the building is completed. Fire extinguishers will be strategically placed inside to allow easy access in case of an emergency. Also, an emergency action plan will be developed that includes what to do in case of a fire. Escape routes and emergency numbers will be important elements of the emergency plan.

Worker Safety

The well-being of those who use the rinsepad is another important safety consideration in the design process. The most basic protection for workers is to insure that they are well trained in both the handling of chemicals and the operation of this facility. This should greatly reduce the possibility of an accident.

Another important safety feature in areas where chemicals are handled is a safety shower and eyewash. A combination unit will be placed inside the rinsepad between the personnel door and the utility sink. It will be placed in this location so that it will be convenient to the area where most of the chemical handling will be performed. Also, it will be close to the door for a quick exit if necessary. A first-aid kit will also be provided in the vicinity of the shower/eyewash assembly.

Personal protective clothing or PPE will not be stored inside the rinsepad. PPE is currently available in the chemical storage facility. It will be the responsibility of the workers to obtain the appropriate PPE from the storage room and to bring it with them to the rinsepad.

Containment

The reason behind any rinsepad design is the desire to contain spills and wastes that inevitably result from the mixing, loading, and rinsing of agricultural chemical application equipment thus preventing damage to the environment. Secondary containment is a term often used in rinsepad design; it refers to the design theory that all containment systems must have backup in case of a failure of the primary system.

Secondary containment is provided throughout this design. The following is a short review of these containment issues and how they have been addressed in the design.

The concrete pad that is the floor of the rinsepad is the most critical aspect of the containment scheme. Only type I or type II concrete mixed according to the proper specifications will be used to build the pad. This concrete mixture will provide a corrosion resistant, almost impervious surface. Because the entire pad and sump will not be completed in one continuous pour, flexible waterstops will be used wherever cold joints are located. As mentioned earlier, all control and expansion joints will be sealed with an appropriate caulk to prevent leakage at these points.

Holding capacity is another important aspect of the containment scheme. Most designers suggest a holding capacity of 110% to 125% of the largest storage tank to be housed in the facility (MWPS, 1991; Wilkinson, 1997; Grisso et al., 1995; Broder, 1990). In this case, there will not be any chemical or rinsate storage in the rinsepad, so the largest spray tank that will be loaded and rinsed was used as a reference. The largest spray tank used at the station is 300 gallons. Using the conservative 125% guideline, the pad should be able to contain at least 375 gallons of fluid. With a minimum curb height of 4 inches, the capacity of this design is approximately 3,900 gallons. This volume will be more than adequate to meet required containment in case of a tank failure.

The sump is an integral part of the pad design. The polyethylene container provides the primary containment and the concrete lined pit provides the secondary containment for this area. As a management practice, leaving any wastewater in the sump will be discouraged, but in the event that this occurs, the concrete walls of this area will be coated with an appropriate sealant. This will prevent seepage of wastewater through the sump walls and into the soil.

A 2-ft wide by 6-inch high concrete slab will secondarily contain the drain that runs the long axis of the rinsepad. After this slab has been poured but is still wet, the drain sections will be set into the slab. This will both hold the drain in place and seal the drain from underneath. Since the slab will be cold jointed to the sloped concrete floor of the rinsepad, waterstops will be used to seal the connection.

Another possible escape route for wastewater is in the form of mist or condensation. This is very difficult to control. One attempt to control this movement in this design is the additional curb height around the sump. These sidewalls will be raised to 3 ft. As mist is created during the rinsing of spray nozzles, most of the water droplets will be deflected by the wall and directed back onto the rinsepad floor. Corrosion resistant panels will be placed on the walls of the rinsepad to contain mist that rises above the 3-ft curb. The top edge of the wall will be chamfered to ease the movement of water downward from the walls to the pad. Flashing will be used at the connection of the wall panel and the concrete wall in order to discourage water movement under the wall panel. Because adequate ventilation will be provided to the facility, condensation should not be an issue. If condensation does become a problem, flashing will be placed along the top of the walls at the connection to the roof. This flashing will direct water back into the facility as opposed to allowing it to flow out of the rinsepad through the soffit vents.

For the most part, secondary containment for the plumbing system will be provided by the concrete pad and sump. One area where another source of containment is necessary is in the connection between the rinsepad and the disposal facility. As noted earlier, a fabricated double walled pipe made of PVC and flexible chemical resistant hose will be used to provide secondary containment.

In order to insure that all waste material is sufficiently contained, a comprehensive management schedule will be developed and practiced. Cracks and expansion joints will be regularly inspected and re-caulked to insure watertightness. The sump should be inspected for leaks and cleaned out when necessary. After each use, wastewater should be pumped out of the sump and into storage. This simple practice will prevent contamination in case there were a crack or leak in the sump. The most likely area for a leak will be along the joint between the foundation wall and the concrete pad. If this were to occur, the fluid would probably move down along the foundation and into the footer drains. Therefore, water from footer drains will be collected periodically and tested for the presence of pesticides. This practice will provide a degree of confidence that the facility is sound. Finally, the plumbing, especially the connection to the disposal area, will be inspected regularly to detect signs of leakage.

Greenhouse Design

The second major component of the rinsepad and disposal system is the greenhouse structure. The principle purposes of the greenhouse are to enclose and protect the soil beds, plumbing, and controls for the disposal system; contain any storage tank or soil bed failures; and to increase evaporation by elevating temperatures around the soil beds. It is essential that the soil beds be protected from rainfall to prevent excess water from entering the system. Any additional water added to the system increases the workload for the soil beds.

A greenhouse structure was chosen because of the control it will provide over the environmental conditions in the disposal area. Corwin (1996) noted that elevated temperatures greatly enhance the degradation and evaporation capabilities of a soil bed system. A greenhouse will provide an inexpensive means of elevating temperatures around the soil beds while at the same time protecting them from precipitation. A secondary issue that the greenhouse will help address is the winterization of the disposal system. The concern in winter, when the system is not in regular use, is freezing of the soil beds and plumbing. It is anticipated that the greenhouse will provide enough heat to prevent freezing inside the disposal area. This will reduce or eliminate the need for any artificial heat around the soil beds and simplify management.

The design issues that are addressed for the greenhouse are basically the same as those considered for the rinsepad facility. Since potentially dangerous materials will be handled in the disposal area, containment is the primary issue. Site selection, structural design, and worker safety are also important design considerations. Because these issues have been covered in depth in the rinsepad design section, they will be discussed here only when modifications are necessary to accommodate the needs of the greenhouse structure or the disposal system itself.

Site

Having chosen the location for the rinsepad, the siting of the disposal facility is partially determined. The disposal system needs to be located in close proximity to the rinsepad for several reasons. The first reason is safety. The longer the distance between the two structures, the longer and more elaborate the rinsate transfer system must be. This increases the risk of an accident or leak in the rinsate plumbing system. By locating the rinsepad and the disposal facility in close proximity this risk is greatly reduced. Secondly, it can be expensive to implement a long-distance transfer system. One example of this problem would be providing secondary containment for the transfer system. Because secondary containment measures have to be devised for all plumbing outside of the rinsepad and disposal areas, expensive double walled pipe must be used. The more pipe is required, the greater the expense. Finally, convenience is a factor. It will be much easier to monitor the disposal area if it is located close to the rinsepad. Also, workers are more likely to inspect the disposal system for safety or containment problems if it is convenient.

In this case the land adjacent to the site chosen for the mixing/loading area is open on three sides: therefore, the disposal system will be located next to the rinsepad (figure 6). However, the principle consideration in the decision as to which side of the rinsepad to place the greenhouse is the issue of shade. Because sunlight is necessary for the operation of the greenhouse, the disposal area needs to be located on a site where shade is not an issue. To determine if this will be a problem on this site, a shade analysis was completed.

The two shade producing obstacles on the site will be the rinsepad itself and a row of 50-ft tall white pine trees located along the gravel drive near the site. Architectural Graphic Standards (1994) provides charts that describe the location of the sun during the seasons of the year. Using the location of the sun during spring, summer, and winter and the heights of the trees and surrounding structures, a shade pattern was determined for our site. Winter was deemed the most critical season for sunlight since the days are shorter and the temperatures are much lower. From the shade patterns, it was determined that the best location for the greenhouse will be on the west side of the rinsepad. Shade from the trees in this scenario will not be an issue. The only shade would come from the rinsepad in the early morning. A small portion of the greenhouse's northwest corner would be shaded before 10 a.m. After 10 a.m., the entire greenhouse would be in full sun for the remainder of the day. Since the greenhouse would be in full sun for the hours of the winter day when sunlight is most direct, the west side of the rinsepad was determined to be the best location for the disposal area.

Traditionally, greenhouses are oriented such that the long axis of the structure runs north/south. This provides for the maximum amount of sunlight in all four seasons. In order to match the orientation of the rinsepad and the gravel drive, the greenhouse will be turned from true north. This rotation will be small and will not cause a significant sunlight reduction.

The greenhouse will be located approximately 3 ft from the rinsepad structure. This will allow the transfer plumbing from the rinsepad to be placed above ground between the two structures, greatly simplifying the design. Access to the disposal area will be provided from the gravel drive that runs in front of the rinsepad: however, the front of the greenhouse will not be located as close to the drive as the rinsepad. To protect the disposal area from accidental contact with farm equipment the greenhouse will be moved 10 ft back from the gravel drive. This location will also provide an easy route from the rinsepad's personnel door to the front of the greenhouse.

Structural Design

Foundation plans and concrete specifications for the two facilities will be virtually identical (figures 16, 17, 18, and 19). A traditional footer with concrete-filled block walls will make up the foundation for the greenhouse structure. Footer drains will run on either side of the foundation walls to reduce soil water content. A gravel and sand subbase as well as a vapor barrier will be placed under the greenhouse floor slab. Type I or II cement mixed to the proper specifications will be used throughout the facility. Waterstops will be used at all cold joints and caulking will be used to seal all expansion joints.

The pad and sump in the greenhouse is designed principally to concentrate wastes in the event of an accident or tank failure. It will not be used on a daily basis to recover rinsate; this fact will greatly simplify the design.

Unlike the rinsepad, the central drainage way in the greenhouse will run along the center of the pad. There will not be any type of specific drain system. The concrete along the central axis of the pad will be sloped so that water will be directed to the sump. The slope on either side of the central drain will be the standard 2 percent. A simple, 2½-inch deep sump will be located in the center of the greenhouse pad. The purpose for this sump will be to provide a small depression out of which wastewater can be pumped back into the rinsate storage tanks in the event of an accidental spill.

The most important design difference between the rinsepad and the greenhouse design is the structure itself. The greenhouse structure will be constructed with a galvanized steel frame. The 8-ft high sidewalls will be anchored to the foundation wall. A traditional peaked roof will be used rather than a quonset-style roof in order to better

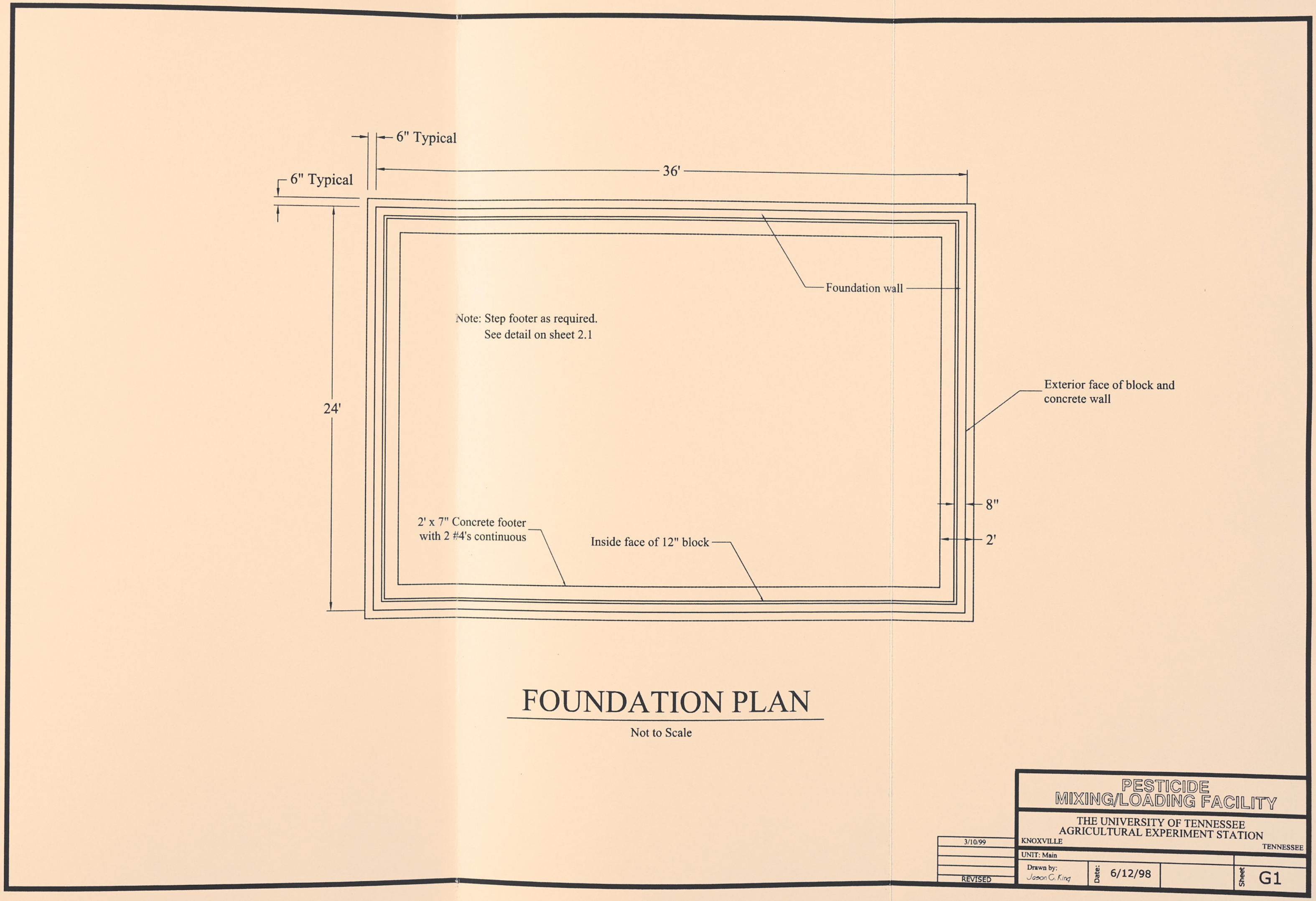

Figure 16. Foundation plan for the greenhouse.

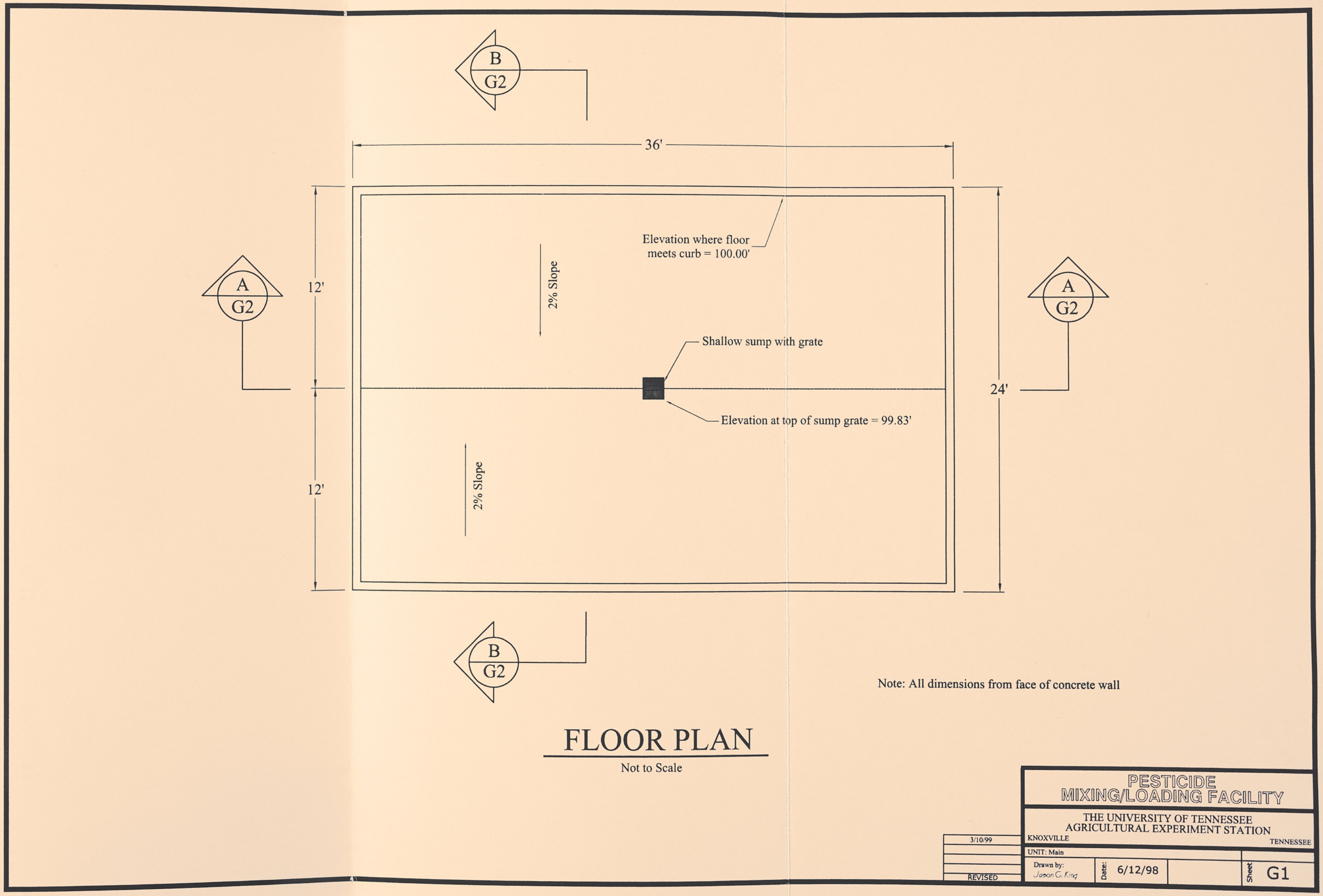

Figure 17. Floor plan for the greenhouse.

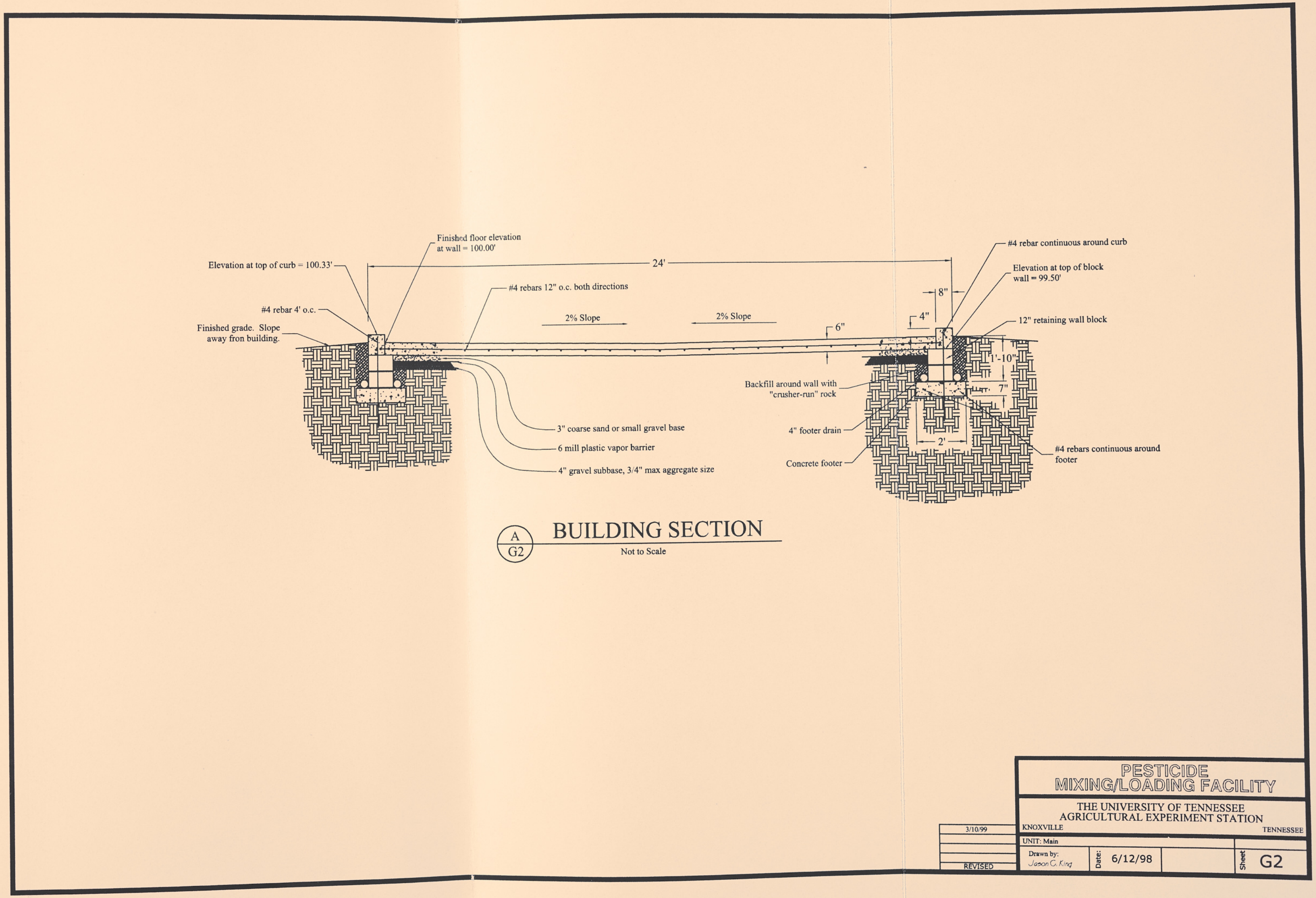

Figure 18. Greenhouse building section cut through the short axis.

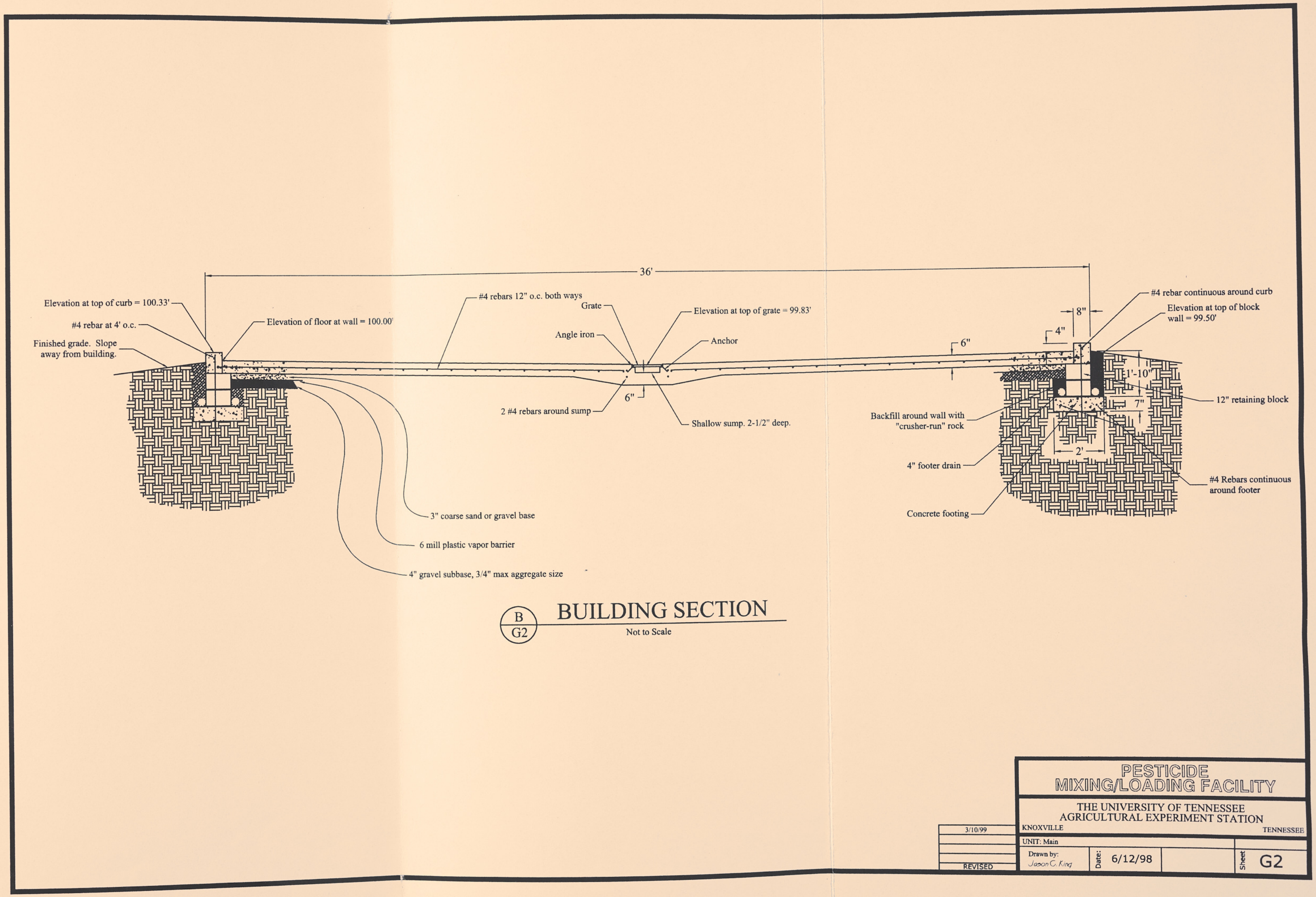

Figure 19. Greenhouse building section cut through the long axis.

match existing buildings on the site. The roof will have a rise of at least 3 inches for every foot of horizontal run. The greenhouse will be covered with an 8-mm thick double walled, polycarbonate sheathing. This rigid covering will make the greenhouse structure more puncture resistant as well as more attractive than a house sheathed with plastic film. The greenhouse will have two doors, one personnel door and one large roll-up service entry. Both of these doors will be located in the south wall of the structure. The personnel door will serve as the primary entrance to the facility. This door will be 42 inches wide and fully weather-stripped. The service door will only be used for loading or removing soil beds from the greenhouse. The dimensions of the service door will be 10 ft wide by 8 ft high.

The greenhouse structure will not be fabricated on-site. It will be purchased from a greenhouse manufacturer according to design specifications and delivered to the site. The staff of the experiment station will construct the foundation and assemble the greenhouse. A complete copy of the specification sheet for the greenhouse is included in appendix B.

Electrical needs inside the greenhouse include ventilation fans, lighting, and possible auxiliary heating. As in the rinsepad facility, the total electrical requirement will be quite low, totaling approximately 10,000 volt-amps of power. The circuit breaker will be enclosed in a NEMA approved cabinet just outside the personnel door. The same type of fluorescent lights specified in the rinsepad structure will be used in the greenhouse. Three electrical outlets equipped with ground fault interrupters will also be placed inside the structure for miscellaneous electrical needs.

A single faucet will supply water inside the greenhouse (figure 14). The line for this faucet will be plumbed into the main line that supplies the rinsepad. A frost proof hydrant will also be used in the supply line to the greenhouse so that water can be independently controlled for the rinsepad facility and the greenhouse in the winter months. The supply line connection will be downstream of the anti-siphon device to prevent any backflow problems. There will be plumbing provided for the soil bed system, but it will be entirely separate from any fresh water supply.

Safety Issues

As with the rinsepad, safety considerations include ventilation, security, fire safety, and worker protection. Ventilation is important not only for the efficient operation of the disposal system, but also for the safety of the facility's operators. Two 24-inch fans will provide the necessary airflow for the building. In order to meet the airflow requirements for the building, the fans will provide at least 6,400 cfm at 0 inches H_20 and 5,700 cfm at 1/8 inches H_2O. The fans will be located on the north end of the structure so that the air will be discharged away from other structures. Because the doors take up most of the open space on the south end of the greenhouse, the inlet shutters will be located on the east and west walls as close to the south endwall as possible.

Locks on both the roll-up door and the personnel door will help to insure the security of the facility. It is imperative that the doors remain locked when the facility is not in use. Also, due to the experimental nature of the facility, only authorized personnel will be allowed access to the greenhouse.

The primary defense against fire will be the strategic placement of fire extinguishers and smoke detectors. An emergency response plan will be developed and integrated with the emergency plan for the rinsepad.

Even though the rinsate stored in the greenhouse will be very dilute, worker safety is still an issue that needs to be considered. Again, the most basic defense for workers is proper training. Since chemicals will not be mixed or handled in the greenhouse, no emergency shower will be provided. Also, because PPE is available in the chemical storage area, these materials will not be available inside the greenhouse.

Containment

In order for the greenhouse design to be successful, a comprehensive plan for containing all waste material in the case of an accident must be developed. As in the rinsepad, primary containment will be provided by the concrete pad.

The capacity of the pad is critical to the effectiveness of the containment strategy. The largest storage tank inside the greenhouse will be an assembly of four 500-gallon tanks, yielding a total storage volume of 2000 gallons. Using the 125% rule, the capacity of the pad must be at least 2500 gallons. The actual volume of wastewater that can be held on the pad is approximately 2,650 gallons.

Though there will be some volatilization of rinsate during treatment in the soil beds, mist will not be a significant issue in the greenhouse since there will not be any rinsing of equipment inside this building. Therefore, the wall panels and flashing used in the rinsepad will not be necessary in the greenhouse. There will be 4-inch curbing around the perimeter of the pad, lower than that in the rinsepad. This height will be high enough to provide the necessary containment volume yet low enough to allow for the easy access of tractors or other machinery when moving soil beds.

All of the secondary containment needs in the greenhouse will be provided by the pad itself. The sump will only be used in the case of a spill so wastewater will not be standing in the sump for any length of time, so the sump will require no containment. The rinsate storage tanks, the plumbing system for the soil beds, and the soil beds will all be secondarily contained by the concrete pad.

Regular maintenance will be required to assure that all wastes will be safely contained in the event of an accident. The primary maintenance concern will be the sealing of expansion joints or other cracks that may appear on the pad. The plumbing, storage tanks, and soil beds of the disposal system will also need to be inspected regularly.

SOIL BED BIOREACTOR SYSTEM

The final component of this rinsate handling facility design is the Soil Bed Bioreactor System (SBBR). The purpose of this component will be to treat pesticide contaminated wastewater. The design for the SBBR system is based on previous work performed by Corwin (1996) and Glover (1998). There are four elements of the SBBR that work together to accomplish the task. These parts include a rinsate storage system, a plumbing system, a control mechanism, and a soil bed system.

Rinsate Storage

Once rinsate has been collected on the rinsepad it will be transferred to the rinsate storage area inside the greenhouse. Since the rinsate cannot be added to the soil bed system all at once, it must be stored. Once the rinsate is safely stored in the greenhouse it will be piped into the soil beds for disposal according to the cycle monitored by the control system.

Four 500-gallon tanks will make up the rinsate storage system (figures 20 and 21). The 2000 gallons of storage will accommodate rinsate volumes based on annual records kept by Lee Ellis at the Plant and Soil Sciences Unit. The average annual amount of rinsate produced is less than 1500 gallons. The storage volume in this system will cover the expected rinsate yield for a single season as well as provide a 500-gallon buffer in the case of an accident or an overproduction of rinsate.

The tanks will be plumbed together for two reasons. First, connecting all the storage tanks essentially creates a 2000-gallon tank. This will make the transfer from the rinsepad much easier since there will need to be only one inlet connection. Second, the plumbing will be valved such that individual tanks can be isolated if desired. This may be necessary if certain rinsates cannot be mixed, or need to be isolated from other chemicals.

The tanks will be arranged in a row along the west wall of the greenhouse (figure 20). This is the most space efficient placement. The tanks will be elevated about 3 ft above the floor of the greenhouse. Frames will be constructed on which the storage tanks will set. The purpose for elevating the tanks is to provide the head necessary to transfer the rinsate from the storage tanks to the control system without any pumping mechanism.

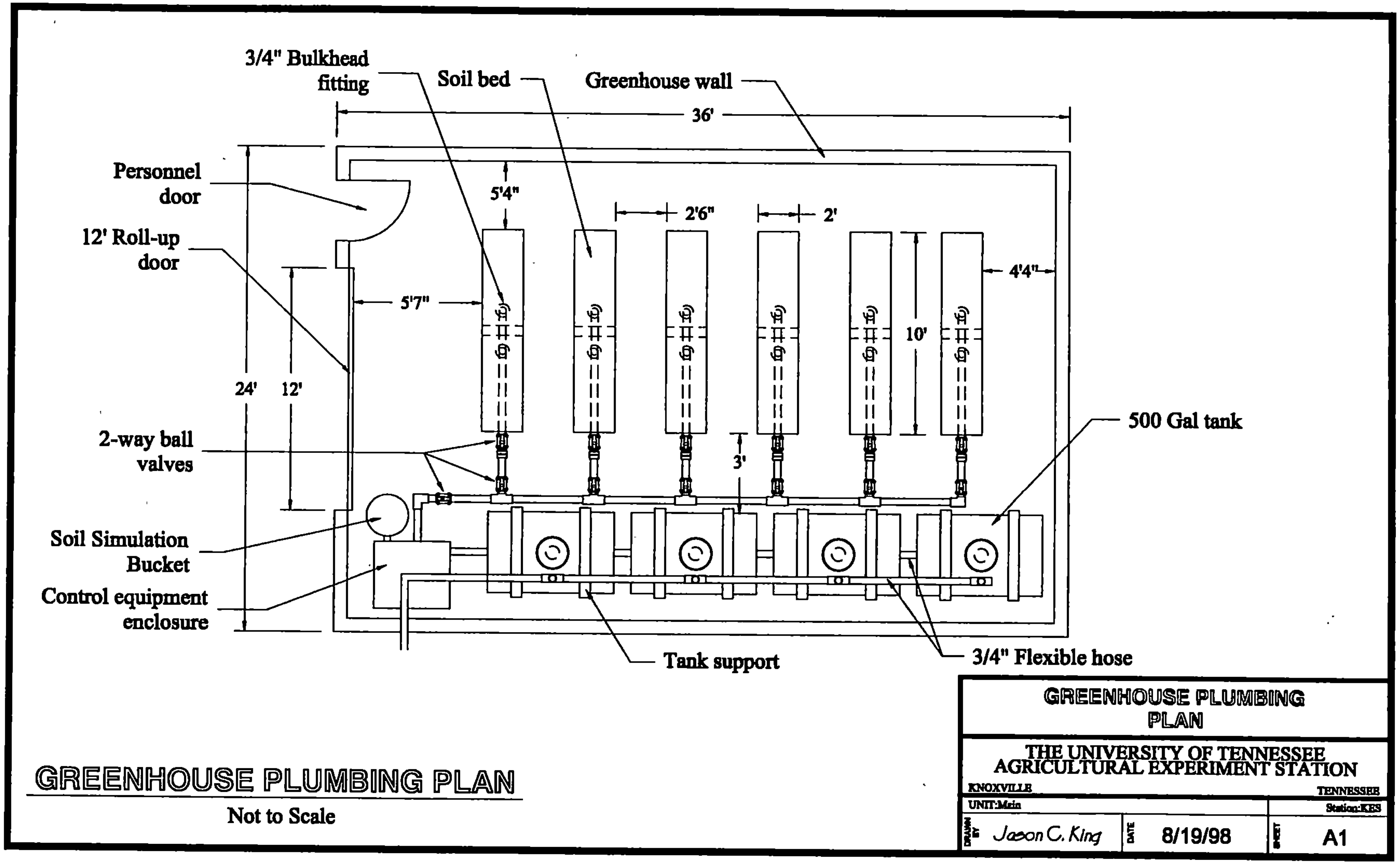

Figure 20. Greenhouse plumbing plan.

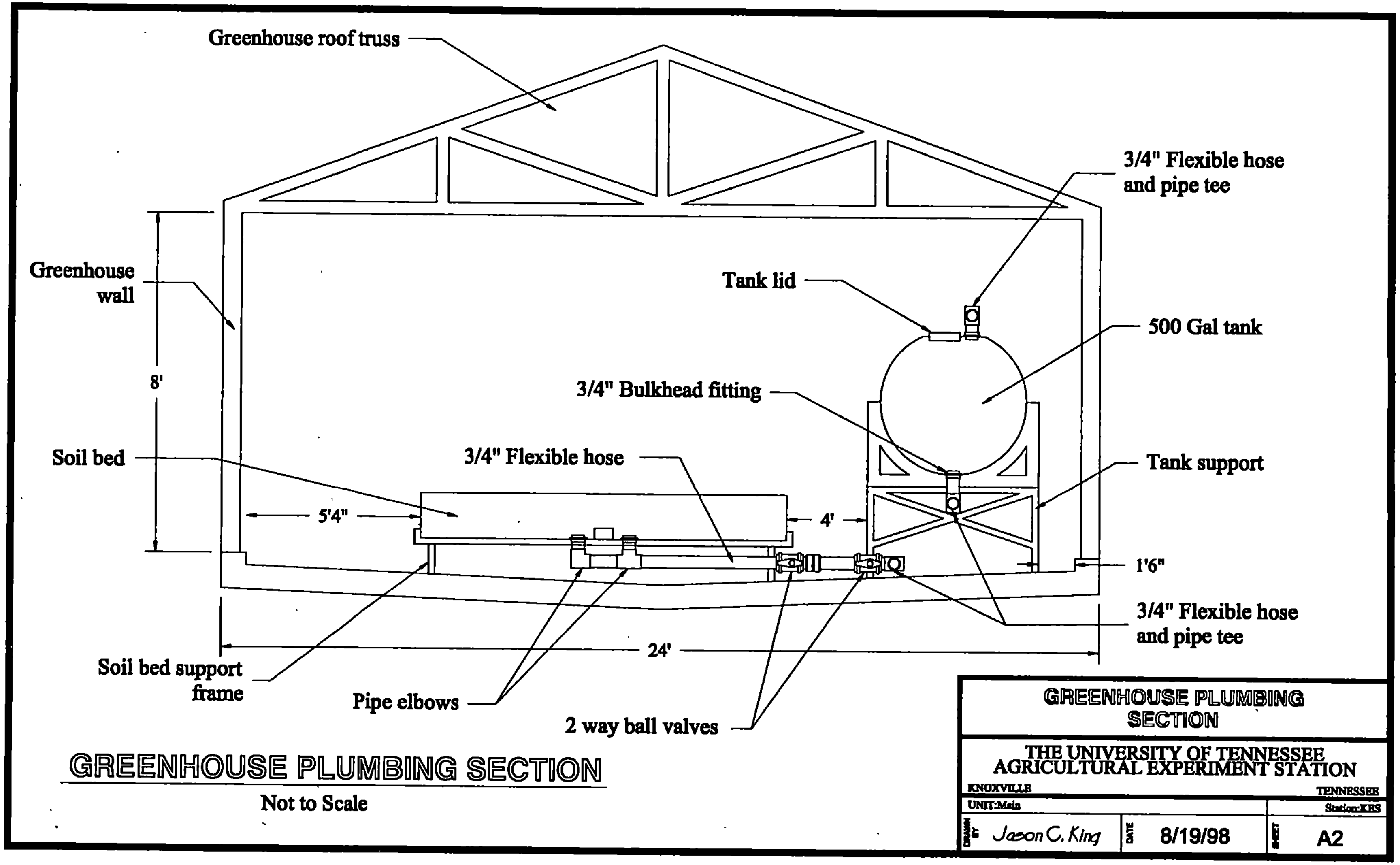

Figure 21. Greenhouse plumbing section.

Plumbing System

The purpose of the plumbing system is to direct the rinsate through the system and ultimately to the soil bed for disposal. There are two subdivisions within the plumbing scheme: the rinsate storage plumbing and the soil bed plumbing.

The rinsate storage plumbing will consist of two main lines running above and below the tanks (figures 20, 21, 22, 23, and 24). These lines will be made of ¾-inch chemical resistant hose. Using hose will increase the flexibility of the system and allow for easy construction and modification. The top line will carry the rinsate into the greenhouse from the rinsepad sump. Along the length of this line, hoses will be plumbed to each tank and attached with a bulkhead fitting. A ¾-inch ball valve will also be plumbed into these drops for manual control. Underneath each tank a line will be connected and will tee into the bottom hose. Again, a ¾-inch ball valve will be plumbed into these lines. Finally, on the bottom line, which carries rinsate to the control system, another ¾-inch ball valve will be plumbed.

The purpose for the ball valves at each tank are to allow total control of the filling and draining of each individual tank. During normal operation, all of the valves would be open. Rinsate will flow into the first tank and, since the bottom valves are open, all of the tanks will fill evenly. If there is a need to isolate a certain chemical or rinsate, the valves in the system can be opened and closed such that only one tank will be filled. In this scenario the wastewater to be separated can be pumped from the rinsepad directly into one tank. The purpose of the last valve on the line to the control system is to allow the complete shut-off of the system in the case of an accident or during maintenance. An overflow prevention system will be installed on the first tank in the greenhouse. If this

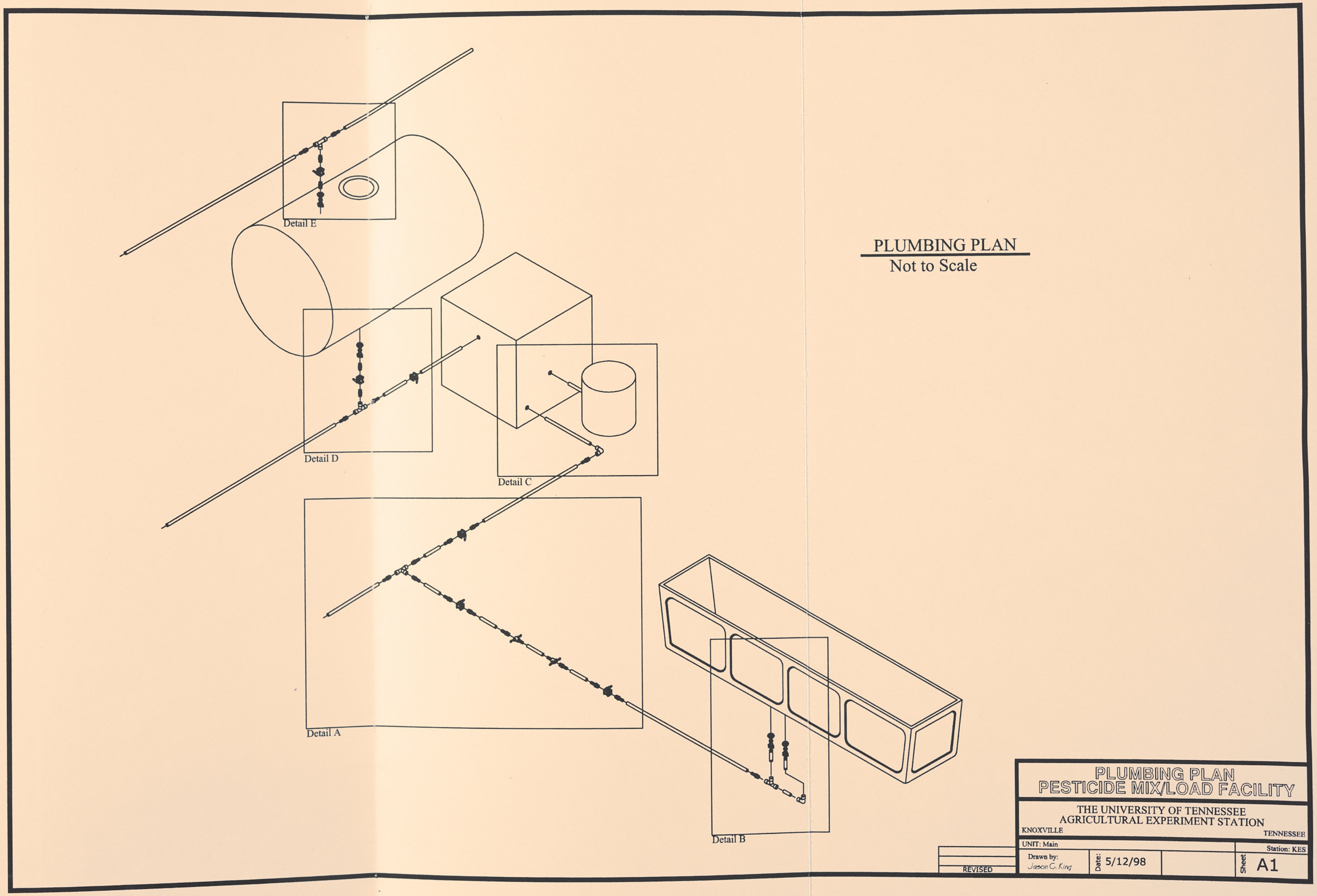

Figure 22. Overview of SBBR plumbing plan.

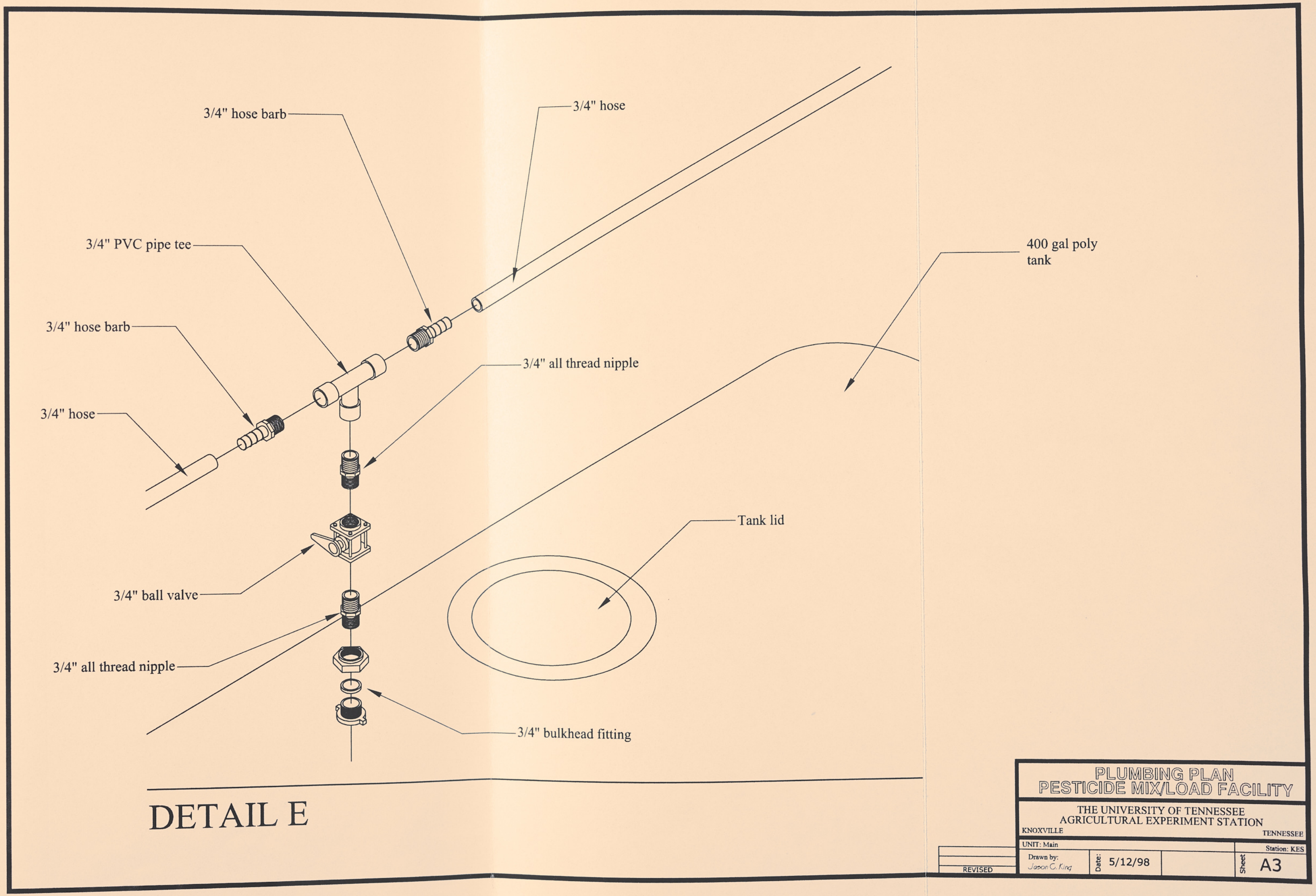

Figure 23. Plumbing above rinsate storage tanks.

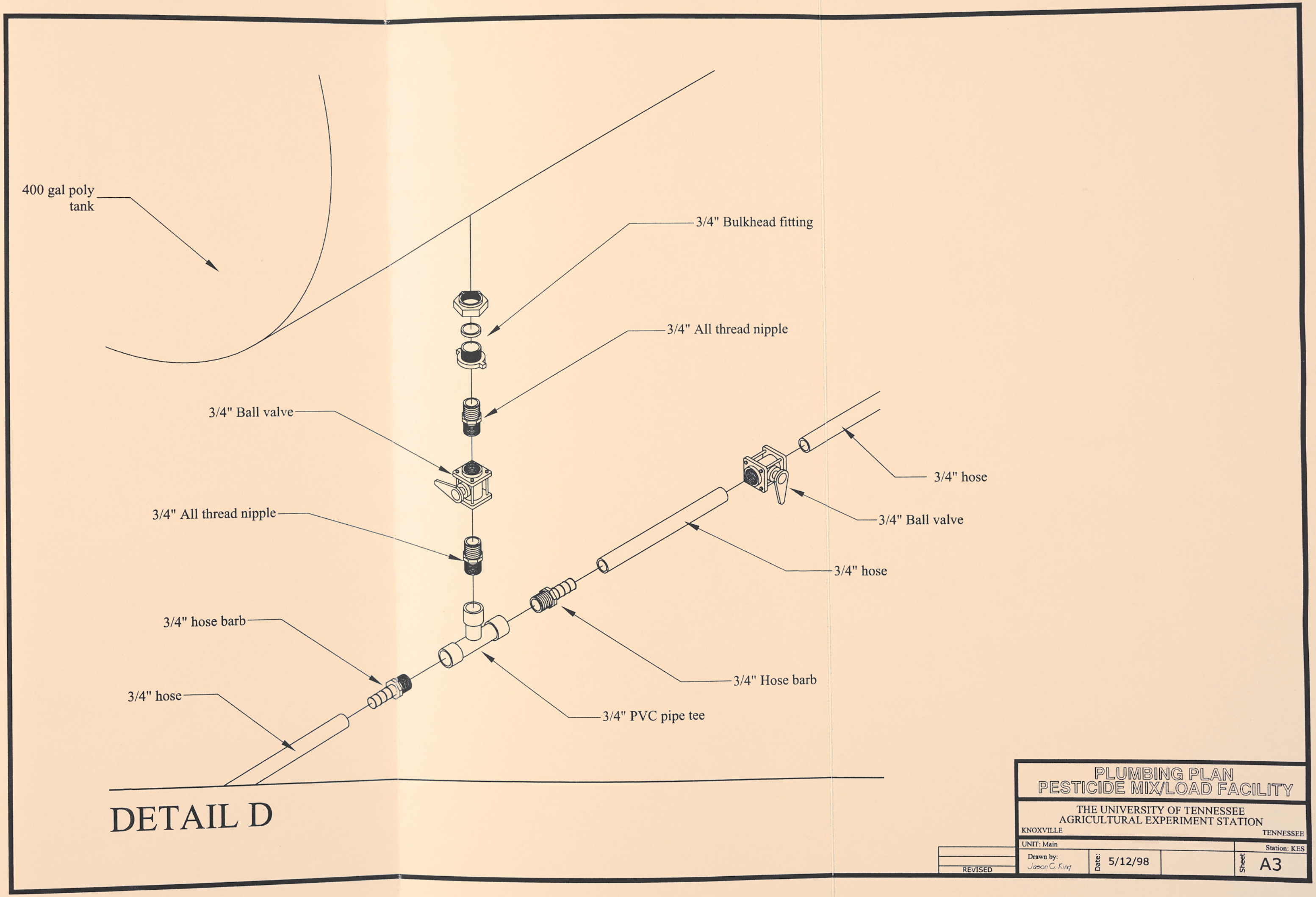

Figure 24. Plumbing below rinsate storage tanks.

first tank gets full, a float switch will activate and signal the sump pump to shut down (figure 14). This will prevent any further transfer of rinsate from the rinsepad until the storage problem is corrected. The second float switch will serve as a backup only.

Plumbing for the soil beds will allow total control of the rinsate flow into each bed (figures 25, 26, and 27). A ¾-inch ball valve will be plumbed into the main rinsate line as it comes out of the control system. This valve will be the overall shutoff for the entire soil bed system. The main line, made of ¾-inch hose, will run the length of the greenhouse. A separate line for each soil bed will tee into the main line. On each soil bed line there will be two ball valves and one quick disconnect. This will allow each soil bed to be easily detached and moved for sampling or maintenance. The quick disconnect will allow the main portion of the hose to be detached and placed out of the way during maintenance operations. This will protect the main line from accidental damage. The ball valves will cut off the flow of rinsate inside the line so that it will not be spilled on the greenhouse floor when detached. Each soil bed line will be connected to the bed using two bulkhead fittings to accommodate a small hump in the center of the bunk feeder. One fitting will be used on either side of this hump to allow for even filling of the bed.

Control System

The control system developed by Glover (1998) will be modified to fill all of the soil beds in this design. The first adaptation that needs to be made involves the design of the soil simulation and constant head buckets. The plastic buckets performed well for the short-term test run by Glover, but there is some concern that these buckets will not be

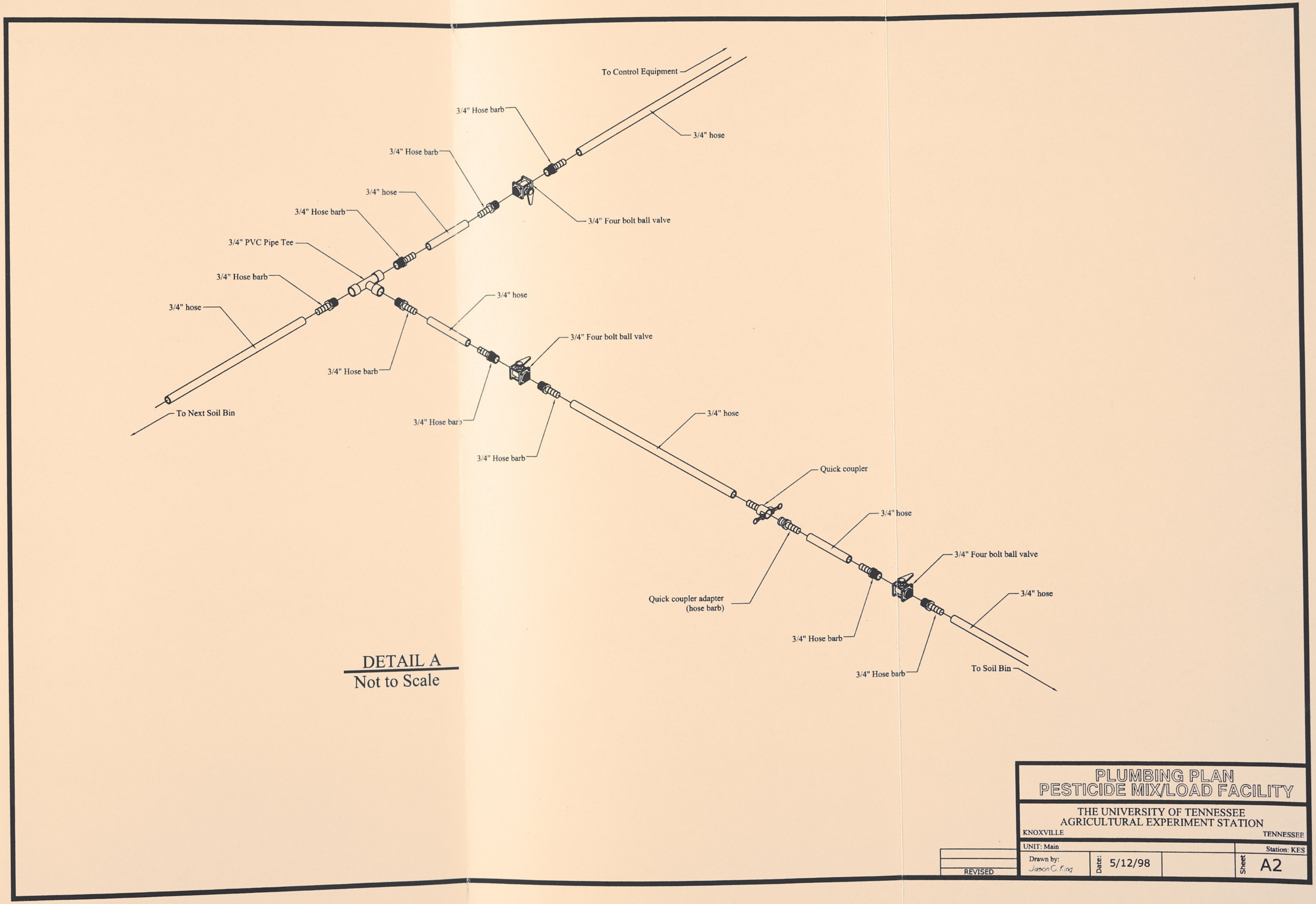

Figure 25. Soil bed supply line detail.

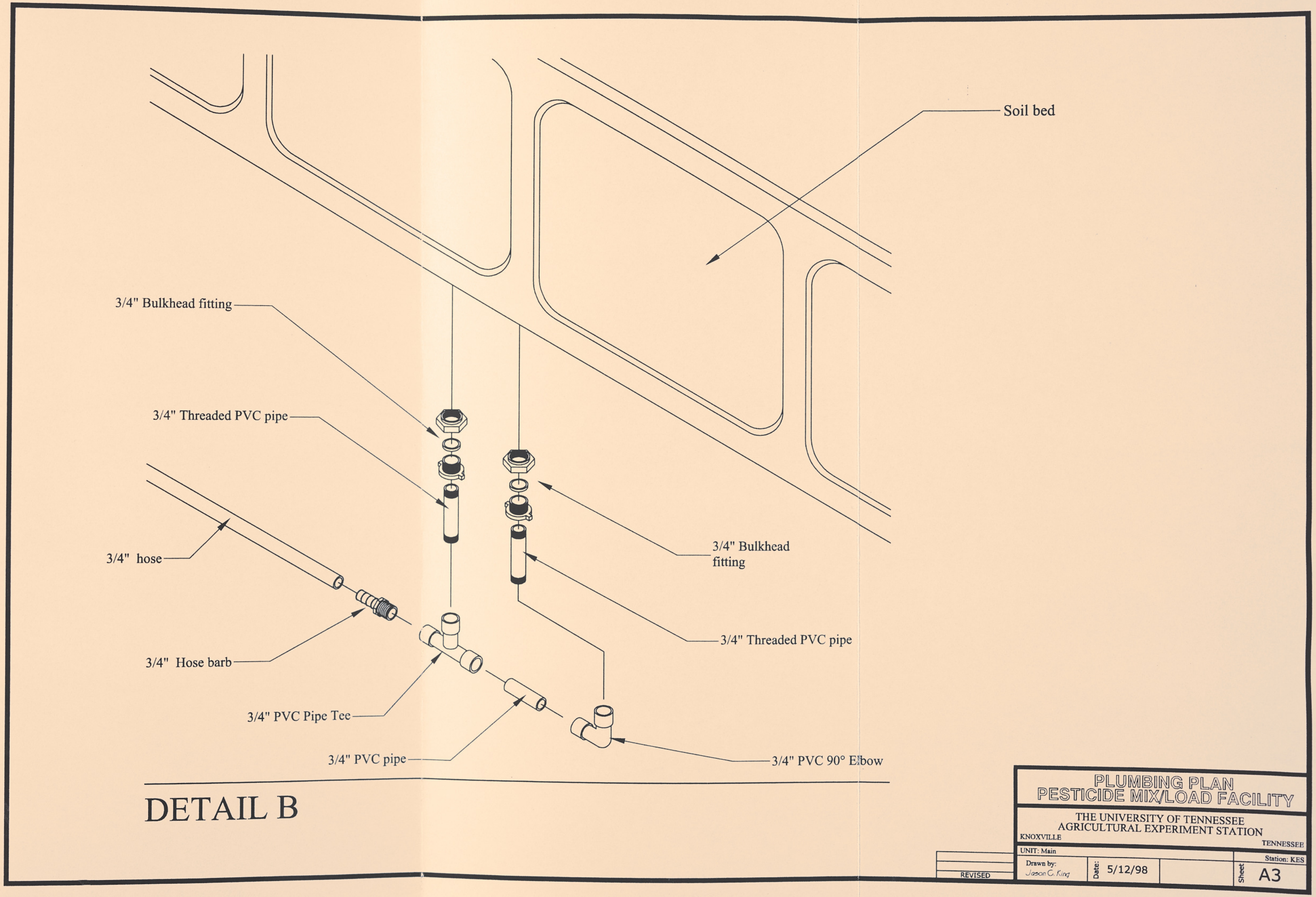

Figure 26. Plumbing under soil beds.

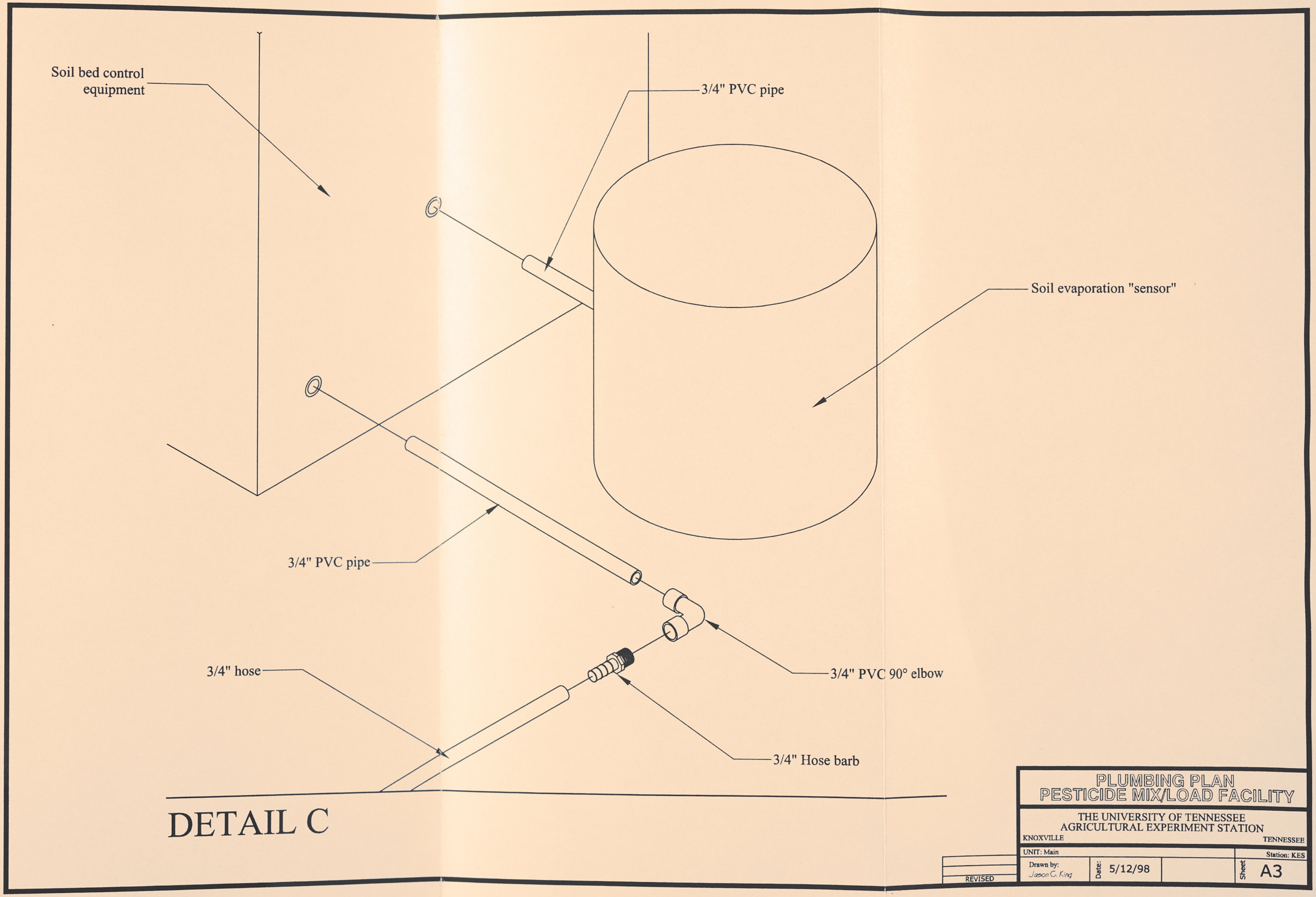

Figure 27. Plumbing between control system and soil bed supply lines.

durable enough to use over an extended period of time. New buckets for the system will be constructed of PVC pipe of the same diameter. The pipe will be cut to length and capped on one end.

The second addition to the control system is a cover apparatus that will prevent light from reaching the control and constant head buckets. During Glover's test, there was a considerable build-up of algae on the surface of the rinsate in these buckets, which could over time cause problems for the system such as reduced evaporation as compared to the soil beds. The addition of a cover would greatly reduce this problem. The soil simulation bucket will not be placed under this cover since it must be open to the environment just as the soil beds are.

The final modification to the control system design involves the float valves. In the previous test the floats did not perform as well as Glover had anticipated. Though they effectively controlled the water level in the constant head bucket, they leaked. In fact, two small metal pans had to be placed under the valves to direct the leaking rinsate back into the bucket. A new type of valve that will not leak under low pressure will be specified to replace the old float valves.

The basic operation of the system will be the same. The only operational difference will be the number of soil beds served by the system.

Soil Bed Design

On the whole, the bunk feeders performed well as soil beds in previous tests. However, a crack did develop in one of the test beds. It was decided that this crack was caused by the frame on which the bed set rather than by the bed itself. Still, this problem raises enough concern to consider an alternate structure to house the soil bed. One alternate option for the soil bed is to have them fabricated specifically for this project using ½-inch high density polyethylene stock. The dimensions for the fabricated bed would be the same as the bunk feeder. The only drawback to this option is the cost. To have a bed of this size fabricated will cost approximately double that of the bunk feeder. The proposed solution to the problem is to use both bunk feeders and fabricated beds in the experimental setup. This would allow a comparison of the two soil bed systems and determine if there is any noticeable difference. If there is an intrinsic problem with the bunk feeders, reducing the number of them in service will reduce the risk of an accident or failure. This test will also help to confirm that the crack in the previous test was only the result of the frame design.

Once a bed design has been chosen, the number of beds has to be determined. This number is based on the amount of rinsate that needs to be treated over the season. Glover noted that the soil beds in his experiment evaporated approximately 131 gallons of rinsate over a 60-day period. Assuming two 60-day periods over the whole season, each bed would evaporate about 262 gallons of rinsate. Using the amount of rinsate produced at the Plant and Soil Sciences Unit as a guide, six soil beds will be necessary. Six beds will give the system a capacity of about 1572 gallons of rinsate per season.

The beds will be arranged side-by-side along the length of the greenhouse structure (figure 20). A small pathway will be maintained between the soil beds so that station personnel can carry out visual inspections. Metal frames will be fabricated to hold the soil beds off the floor and give them extra support (figures 28 and 29). A dolly will be fabricated with heavy-duty casters for moving the soil beds when they need to be

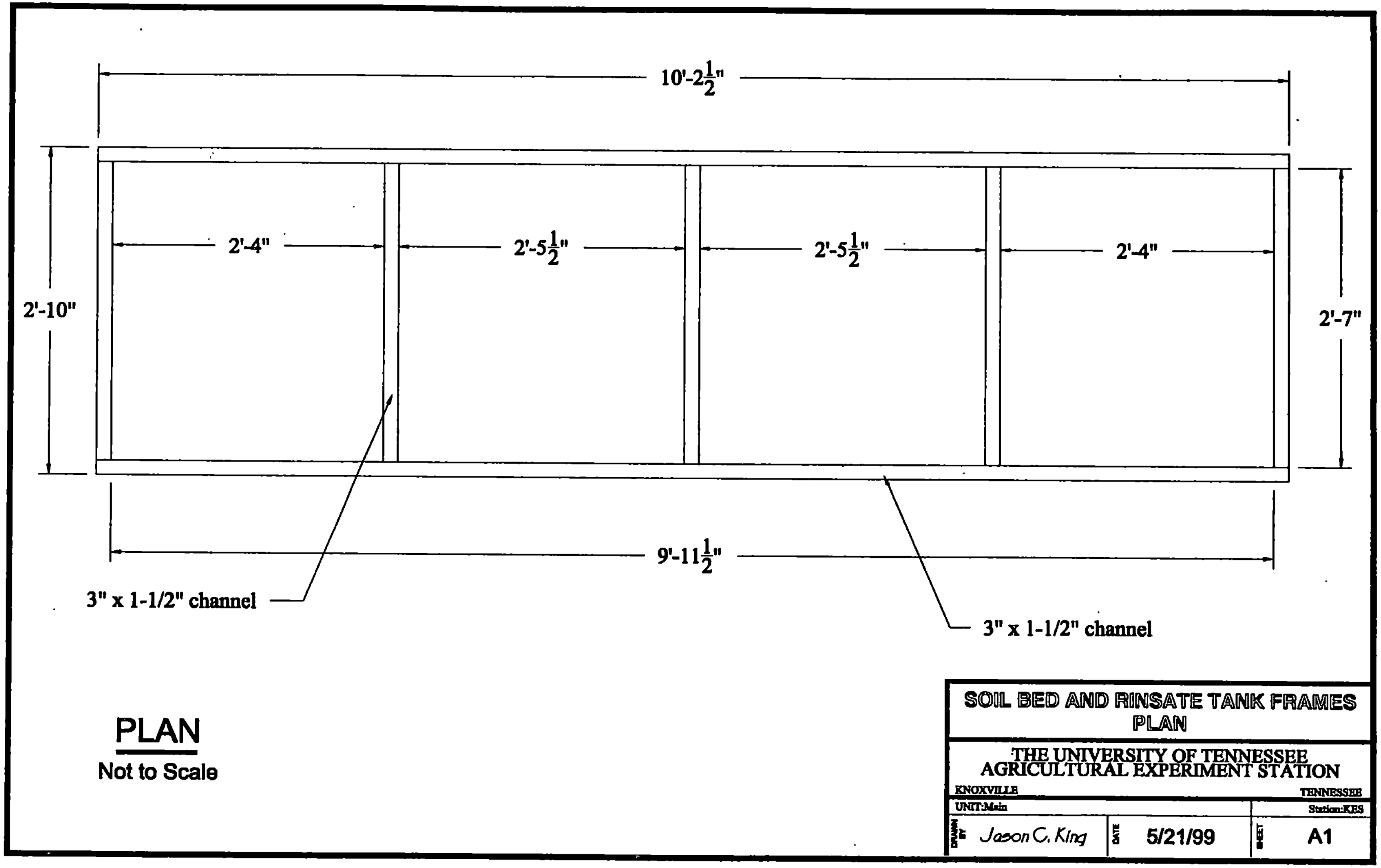

Figure 28. Soil bed frame plan.

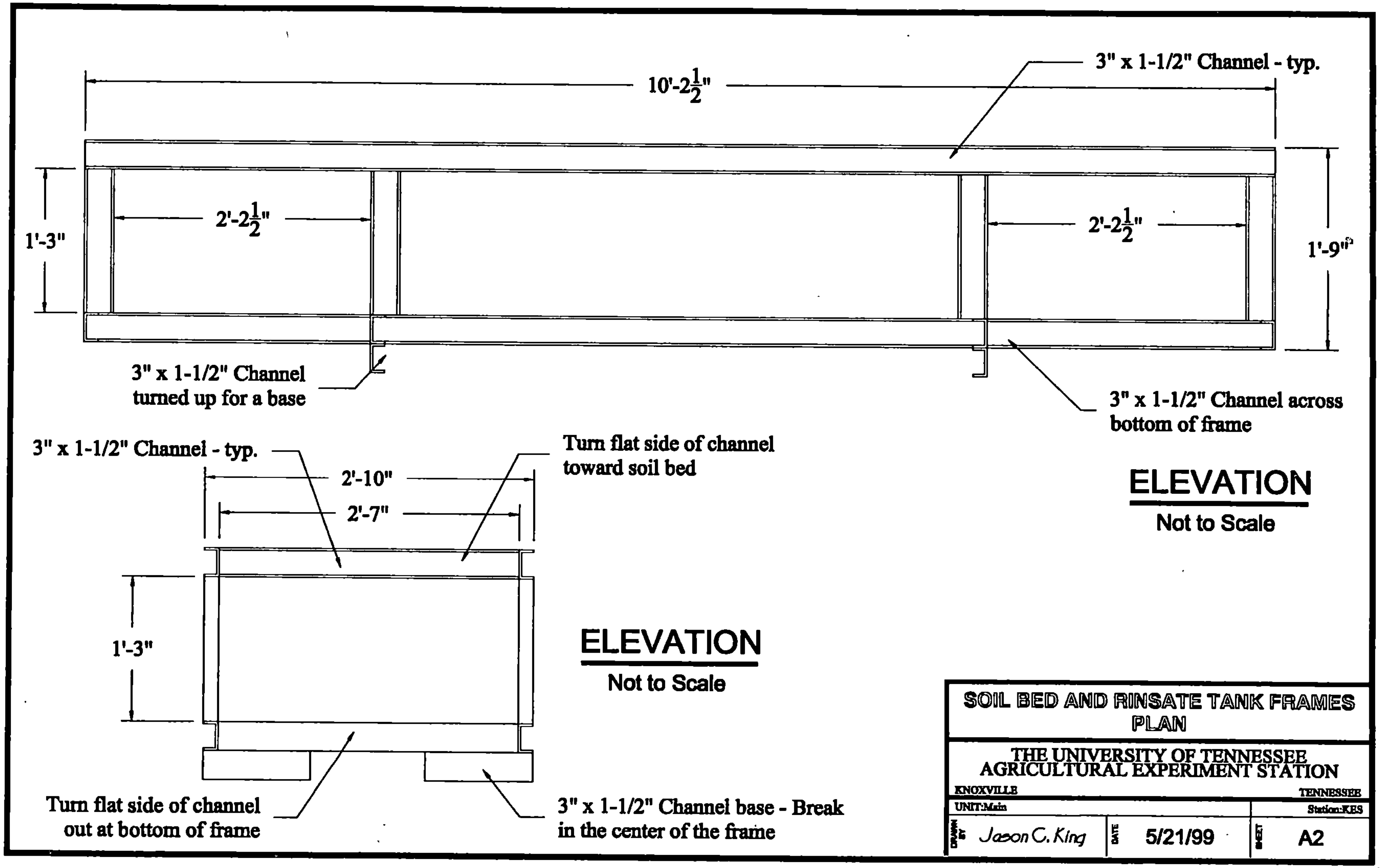

Figure 29. Soil bed frame elevations.

sampled. The beds will be lifted with a jack so that the dolly can be placed under the frame. Once securely on the dolly, the soil bed can be rolled to the greenhouse service door and moved for sampling or maintenance.

CHAPTER 4

SUMMARY

A comprehensive pesticide handling facility that includes an effective means of waste disposal would be of significant benefit to many pesticide applicators as well as to the environment. The design discussed here will meet this need inexpensively and safely.

The three goals outlined for the mixing/loading facility have been considered in the design of the rinsepad. A concerted effort was made to use the least expensive building type and equipment possible without sacrificing the safety of the workers or environment. The initial cost estimate for the rinsepad and the greenhouse facilities (not including disposal system components or labor) was approximately $30,000. Because this system was specifically designed as a research facility, extra precautions were taken which increased the total cost. The producer may be able to find areas where costs could be reduced, but modifications should be made with extreme care. Special consideration must be given to the possibility of failure when cheaper components are used due to the legal and environmental ramifications associated with contamination problems.

Because containment is the critical purpose for a rinsepad, special emphasis was placed on all aspects of chemical containment. This issue was reviewed numerous times during the design process and no shortcuts were allowed. The facility was specifically crafted to meet the needs of the Knoxville Experiment Station in Knoxville, TN. Most importantly, the system design is based on substantial previous research and will be effective for its purpose, collecting and containing pesticide wastes. It should also be noted that the basic components of this design would be applicable to any rinsate producing operation including nurseries, golf courses, and lawn care companies.

A mixing/loading facility is only half of the facility needed for safe pesticide handling. Rinsate and other wastes generated must also be disposed of in a safe manner. The goals set forth at the beginning of this investigation for the on-site disposal system were also met in this design. The result was a simple system based on the research of Corwin (1996) and Glover (1998) that can inexpensively treat pesticide wastes. All applicable federal and state laws were investigated and incorporated into the design so that complete compliance could be assured. Finally, the system design will be effective for the disposal of pesticide wastes and will be a powerful tool for today's pesticide applicators.

CHAPTER 5

RECOMMENDATIONS FOR FURTHER WORK

Due to time constraints there are a number of issues that were not investigated in regard to this project. These issues can be grouped into two principal areas: a comprehensive management plan and optimization of the full-scale system.

A detailed management plan will be essential for the successful operation of the rinsepad and the disposal facility. The first management issue is the operation of the facility. A number of functions such as packing the soil beds, operating the sump, and properly rinsing spray tanks need to be considered so that specific, easy instructions can be written. These instructions will be important guidelines for the operators of the system.

Another important aspect of this plan should be maintenance. The rinsepad in particular will require a meticulous maintenance routine since potentially hazardous chemicals will be used in this facility on a regular basis. Cracks and expansion joints must be checked and re-caulked periodically to insure containment of all chemicals. Protocols for sump cleaning will have to be outlined. The greenhouse will also need to be maintained properly. Soil beds and storage tanks will need to be checked for leaks. Also, the control system will have to be kept in proper working order. The issue of maintenance needs to be considered exhaustively so an effective plan can be developed. If the resulting plan is followed, the risk of accident will be greatly reduced.

A sampling plan will be critical to the proper functioning of the rinsepad and disposal facility. It will be the sampling plan that will insure degradation of the rinsate that is added to the soil beds. Additionally, sampling of the soil on the site and water from the footer drains will help prove that no contamination of the environment is occurring. Protocols should be developed for each of these processes. A standardized procedure will allow the sampling tests to be analyzed over time. Specific procedures will also make these tests easier for farm personnel to perform accurately. Finally, a schedule of all sampling operations should be developed so that nothing is omitted or forgotten.

A training plan or handbook should be developed so that those who are authorized to use the facility will be familiar with all aspects of its operation. Training of workers will be important not only for the efficient operation of the system but also to help prevent accidents or injury resulting from an insufficient understanding of the facility and its purpose.

Finally, an emergency response plan should be developed. Although there are a number of safety features built into this facility, accidents are always possible. It is important for the operators of the system to know what to do in the case of a fire, tank failure, major spill, equipment failure, or other major problem. The use of such a plan will greatly reduce the scope and consequences of many types of accidents.

The second major area of research that needs to be continued with this project is an optimization of the farm-scale system. A number of issues need to be resolved so that the system will operate at its maximum potential. The cycle duration should be reanalyzed to make sure that the 5-day cycle works best. The control system needs to be monitored for possible areas of improvement. Adverse chemical interactions need to be investigated so that potential problems in the soil beds can be eliminated. Environmental issues such as soil type, temperature, and airflow should be revisited so that the best performance can be achieved.

These are only a few of the possible issues that need to be addressed once the facility is built and in operation. In order to achieve the best possible results, these considerations must be investigated.

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APPENDICES

APPENDIX A

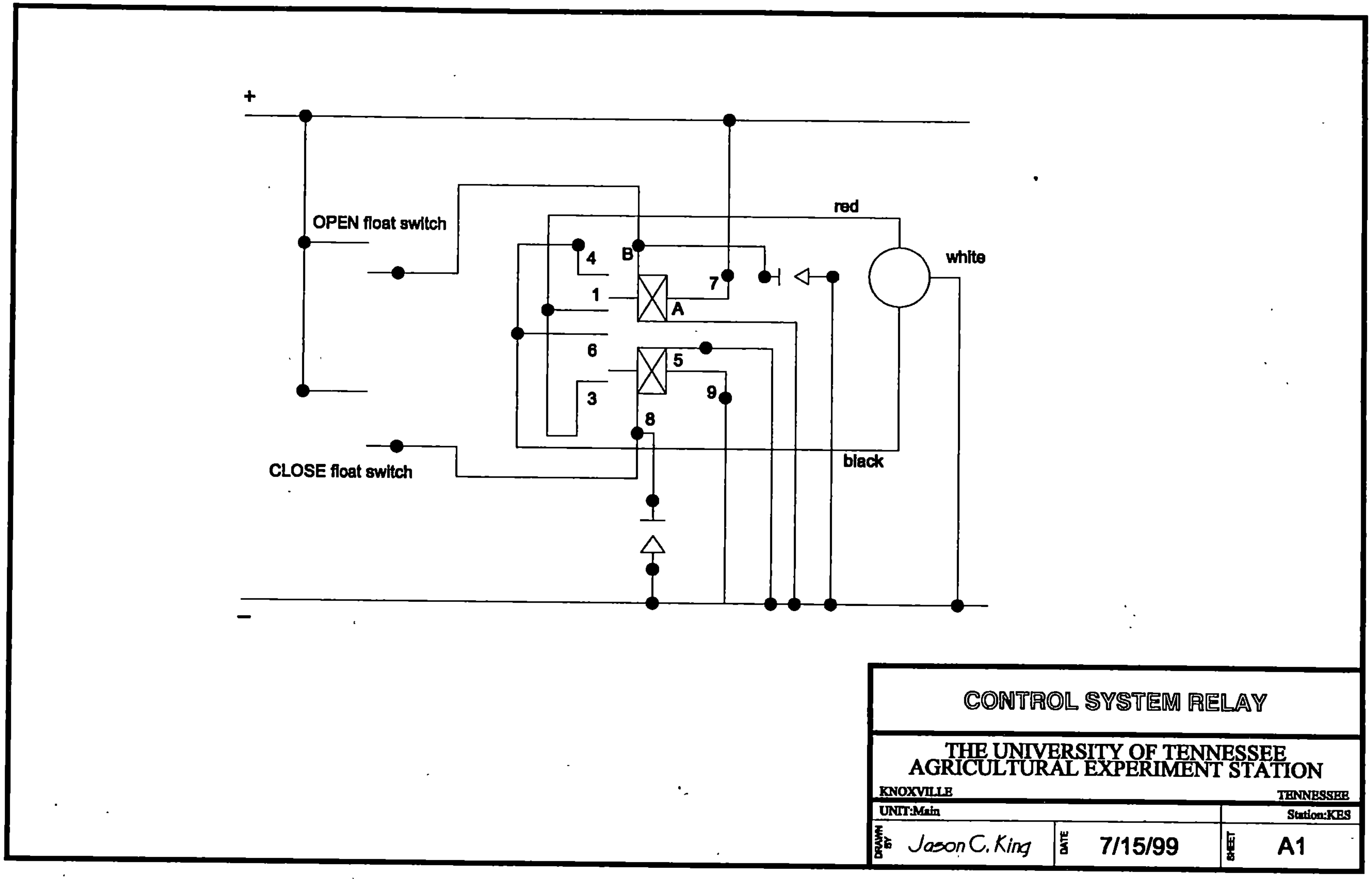

Figure A1. Schematic for relay in control system.

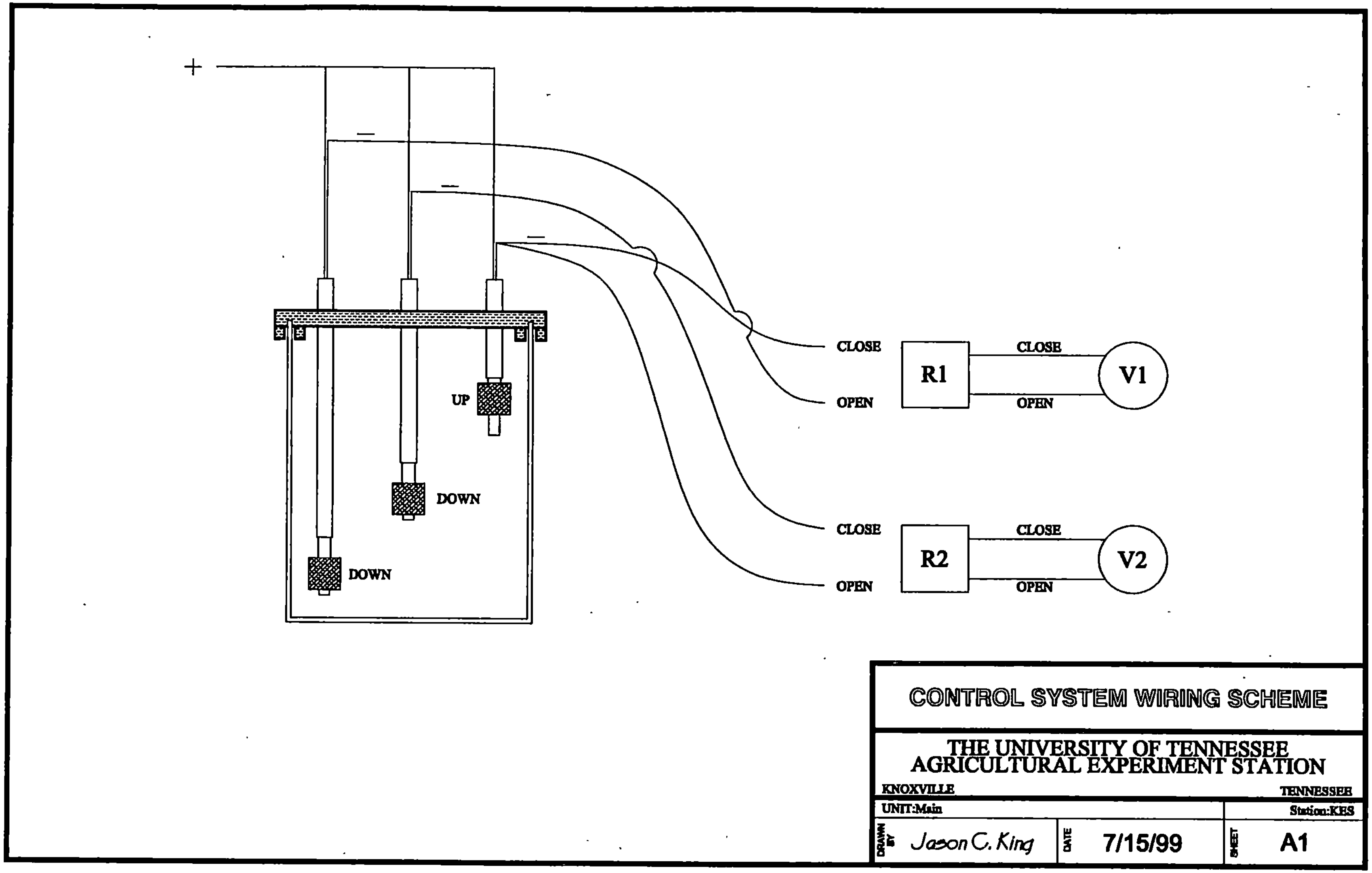

Figure A2. Wiring schematic for float switches in control bucket.

APPENDIX B

1. BACKGROUND

1.1. The purpose of this bid is to provide a functional, well-designed, and attractive greenhouse structure. The proposed floor plan and elevations are shown on the attached drawings.

1.2. This building will be used in conjunction with a pesticide remediation research project.

2. GENERAL BID INFORMATION

2.1. Experiment station personnel will erect the proposed greenhouse on the Knoxville Experiment Station in Knoxville, TN, which is located at the address shown on the requisition.

2.2. Questions regarding this bid may be directed to Dr. John Hodges, Superintendent of the Knoxville Experiment Station, at voice 423-974-7201 or FAX 423-974-9462.

2.3. The drawings in this bid have been reduced and attached for your convenience. If you require full size drawings to prepare your bid response, please contact Jason King, Graduate Research Assistant, for full sized copies. He may be reached at 423-974-7266 or FAX 423-974-4514. Please allow a minimum of three(3) working days for delivery of plans.

2.4. It is the sole responsibility of the successful bidder to:

2.4.1. Furnish all materials required to erect the greenhouse structure on the foundation provided by the owner.

2.4.2. Arrange and schedule with the station superintendent timely delivery of all the items specified herein.

2.4.3. Include one complete set of structural plans for the structure.

2.4.4. Include descriptive literature describing and specifying in detail the parts of the structure provided.

2.4.5. Include a complete set of instructions for the successful erection of the structure.

2.4.6. NOTE: No storage is to be arranged or furnished by the bidder. All materials will be stored on site until construction begins.

3. SITE AND FOUNDATION WORK

3.1. Site excavation will be the sole responsibility of the owner. No earthwork is included in this bid.

3.2. Foundation and anchorage design. The successful bidder has the following responsibilities in the area of foundation and anchorage design.

3.2.1. Anchoring system required for the structure shall be clearly marked on the structural plans.

3.2.2. Anchorage system shall be designed to carry the loads imposed by the structure.

3.2.3. Building footings will be installed by the owner. Installation of the foundation is not included in this bid.

3.2.4. Foundation design loads and/or column reactions for the various load combinations imposed on the structure shall be provided so that the owner may design the foundation.

4. GREENHOUSE STRUCTURE SPECIFICATIONS

4.1. General Requirements.

4.1.1. Metal greenhouse structure shall be the product of a recognized greenhouse system manufacturer who has been in the practice of manufacturing greenhouse structures of the size and complexity requested herein for a period of no less than 5 years. The manufacturer shall be chiefly engaged in the practice of designing and fabricating greenhouse structures.

4.1.2. This building shall include all structural frames and framing members, connection bolts, wall and roof panels, doors, ventilators, flashing, fasteners, and all other items required to erect and finish the building specified.

4.1.3. The building width and length shall be measured from the inside face to inside face of the wall covering. The structure shall be 24 feet wide and 36 feet long.

4.1.4. The sidewall height shall be a minimum of 8 feet.

4.1.5. The roof slope shall have a rise of at least 3 units for each 12 units of horizontal run.

4.2. Design.

4.2.1. Dead load shall consist of the weight of the structural frame and all other materials of the building system.

4.2.2. The structure shall be designed for a roof snow load of at least 20 lb/sq. ft. or as specified by local codes, whichever is greater.

4.2.3. The structure shall be designed for a live load of at least 10 lb/sq. ft.

4.2.4. Design wind load for this building shall be based on a basic wind speed of 70 mph or as specified by local codes, whichever is greater. Wind loads shall be computed and applied in accordance with local codes.

4.3. Structural Framing

4.3.1. All framing members shall be shop fabricated for bolted field assembly. Self –tapping screws are also acceptable.

4.3.2. Galvanized steel shall conform to ASTM A653, G 90 coating designation or better.

4.3.3. Aluminum-zinc coated steel shall conform to ASTM A 792, AZ 55 coating designation or better.

4.3.4. All welds shall be hot-dipped galvanized after fabrication.

4.4. Roof and Wall Covering

4.4.1. Both roof <u>and</u> wall covering shall be GE Lexan® Thermoclear® Dripgard™ or equal clear 8-mm thick rigid double-wall polycarbonate UV resistant greenhouse covering with condensate control treatment.

4.4.2. All panels shall attach with a system of extrusions at all ends and joints.

4.4.3. Fasteners shall meet or exceed the following specifications.

4.4.3.1. Fasteners shall be hex head, self-tapping, and have large washers for support.

4.4.3.2. Fasteners shall be aluminum, stainless-steel, carbon steel with aluminum or stainless steel capped heads, or equally corrosion resistant material.

4.4.3.3. Fastener spacing shall be as specified by the building or panel manufacturer for the spans and loading conditions of this building.

4.4.4 Caulk, sealant tape, neoprene washers, etc. shall be furnished as required to erect the building.

4.4.5. Flashing and/or trim shall be furnished at the rake, corners, and eaves, at framed openings, and whenever necessary to provide weather-tightness and a finished appearance.

5. BUILDING ACCESSORIES

5.1. A 10' wide roll-up door shall be furnished with the greenhouse structure. The door shall be located as shown on the attached floor plan.

5.1.1. The successful bidder will provide all necessary fasteners, jambs, headers, and flashing.

5.1.2. Perimeter of the door shall be weather-stripped to insure a leak-proof structure.

5.1.3. Door shall be capable of holding at least the same design wind pressure as the rest of the building.

5.1.4. Door will be manually operated.

5.1.5. Door must be able to be securely locked.

5.2. One 42" walk (passage) door shall be included in the structure. It should be located as shown on the attached floor plan.

5.2.1. Door shall include fasteners, jambs, headers, flashings, and metal thresholds.

5.2.2. Door shall be insulated and door framing shall be aluminum.

5.2.3. Door shall be fully weather-stripped.

5.3. Fans and shutters shall be included in this bid according to the following requirements. See attached drawings for approximate location of fans and shutters.

5.3.1. Fans

5.3.1.1. Two 24" fans shall be provided. 24" fans shall meet the specifications below.

5.3.1.2. Blades shall be reinforced polycarbonate, epoxy coated steel, or equal corrosion resistant construction.

5.3.1.3. Motors shall be two-speed, totally enclosed, single phase, 240V, 60Hz and sized to be non-overloading over the performance curve of the fan.

5.3.1.4. Each 24" fan shall move a minimum of 6,400 cfm at 0 in H_20 and 5,700 cfm at 1/8 in H_20.

5.3.1.5. Housing shall be galvanized steel, aluminum, stable polycarbonate or equal corrosion resistant construction.

5.3.1.6. Fans shall be equipped with PVC coated or galvanized wire guards on the inlet side.

5.3.2. Shutters

5.3.2.1. Fans shall be equipped with automatic shutters on the discharge side of structure.

5.3.2.2. Inlet shutters shall be provided at the location shown on the attached floor plan and elevations. Shutters shall be sized to provide 2.25-sq. ft. per 1000 cfm of fan capacity at 1/8 inches of water pressure.

5.3.2.3. All shutters shall have aluminum or reinforced fiberglass blades.

5.3.2.4. All shutters shall have aluminum, or reinforced fiberglass frames.

5.3.2.5. Inlet shutters shall be motorized. Voltage to be same as fan motor voltage.

5.3.3. Controls

5.3.3.1. Two-stage thermostats or equal control packages as required to control the fans specified above shall be provided. This thermostat or control package must provide staging for the fans and must be 100% compatible with the fans.

5.3.3.2. One single-stage thermostat shall be provided to operate the inlet shutters if this function is not included in the above control package.

5.3.3.3. All thermostats shall be the hydraulic capillary type.

5.3.3.4. All thermostats shall have NEMA 4X enclosures.

6. PLUMBING

6.1. No plumbing is included in this bid.

7. ELECTRICAL

7.1. No electrical equipment, except ventilation equipment discussed in item 5.3, is included in this bid.

8. HEATING

8.1. No heating equipment is included in this bid.

9. WARRANTY

9.1. The successful bidder shall provide a minimum one(1) year weathertightness warranty for the structure.

9.2. The successful bidder shall provide a minimum one(1) year warranty against defects in materials and craftsmanship.

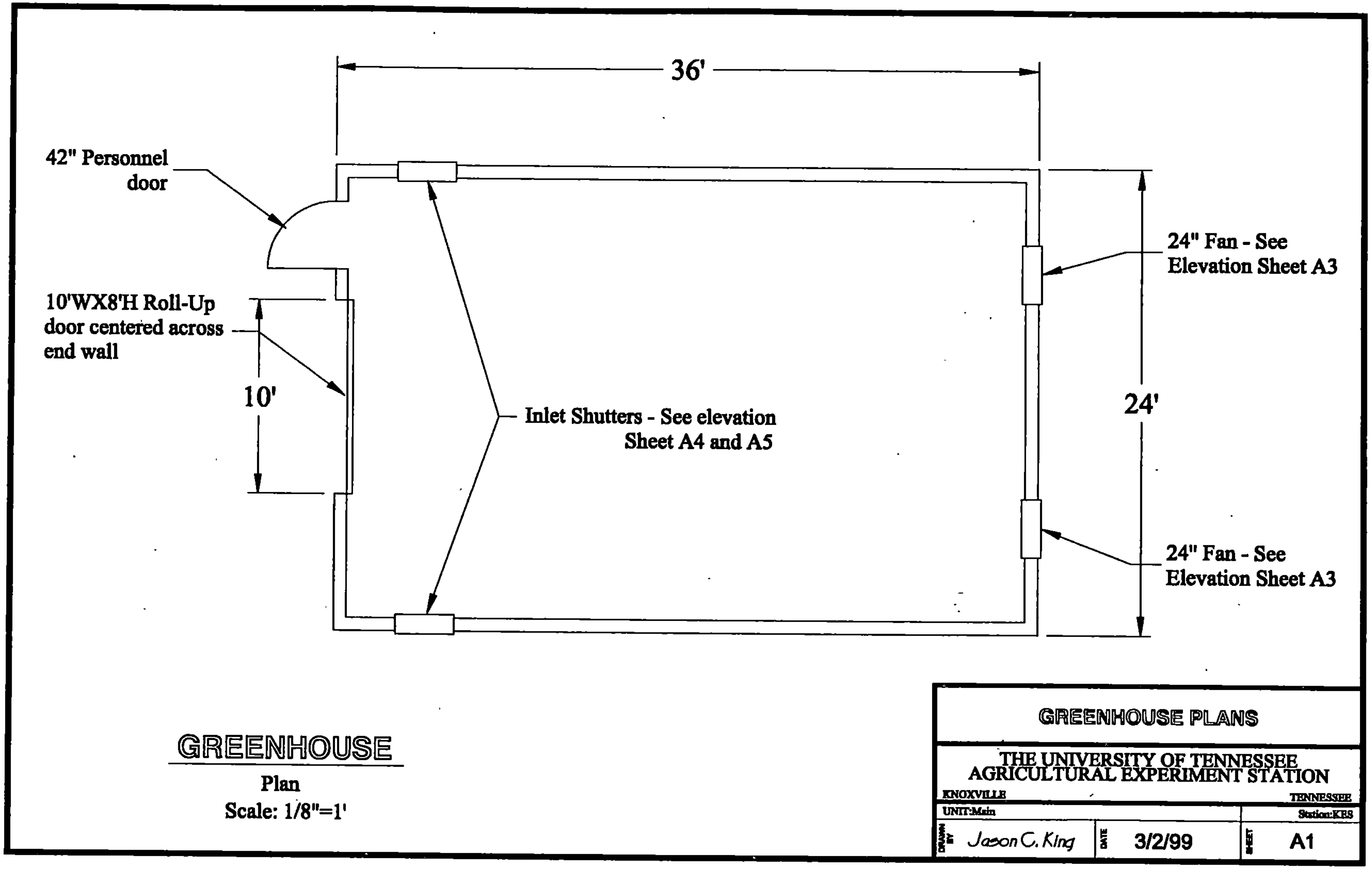

Figure B1. Plan for greenhouse specifications.

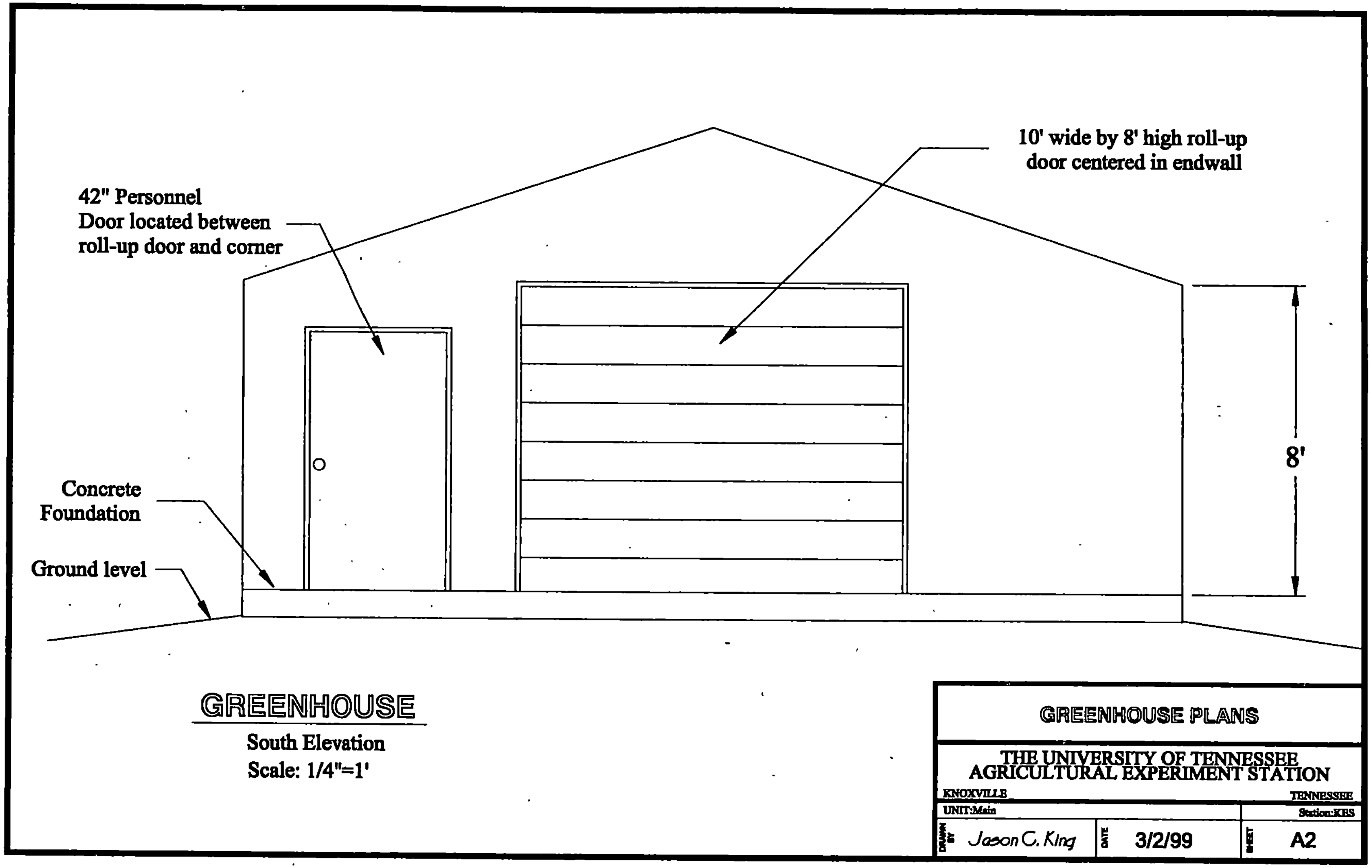

Figure B2. South elevation for greenhouse specifications.

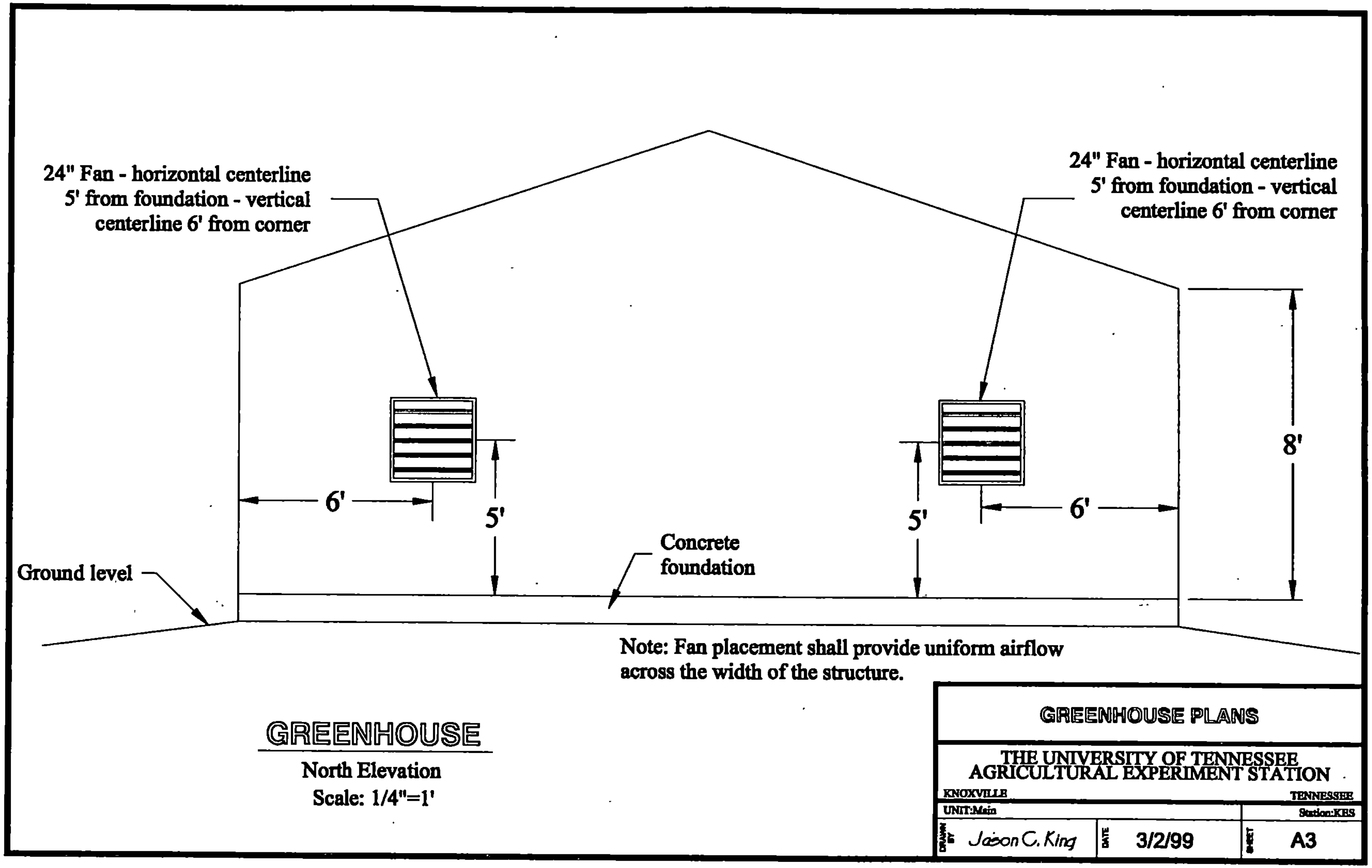

Figure B3. North elevation for greenhouse specifications.

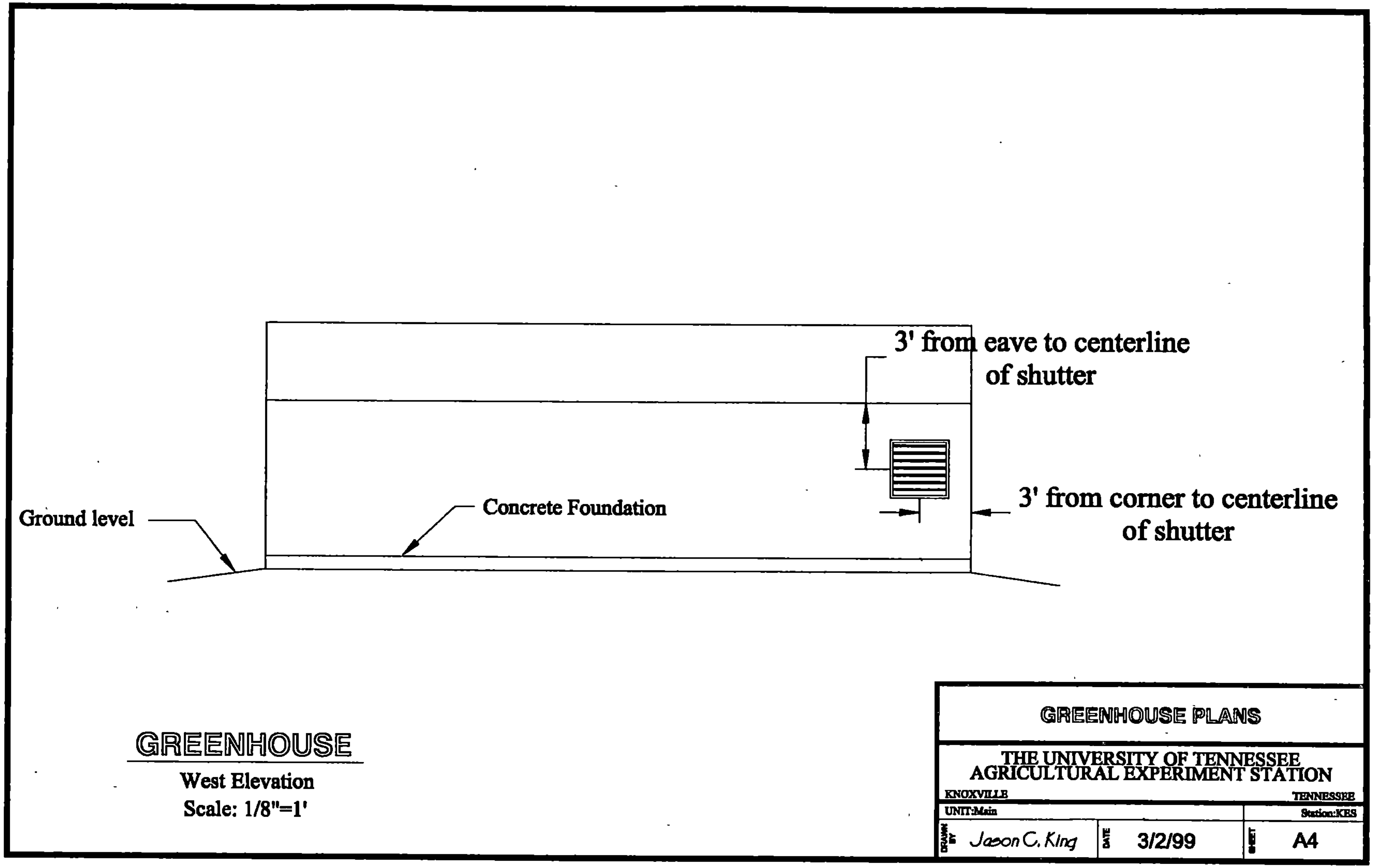

Figure B4. West elevation for greenhouse specifications.

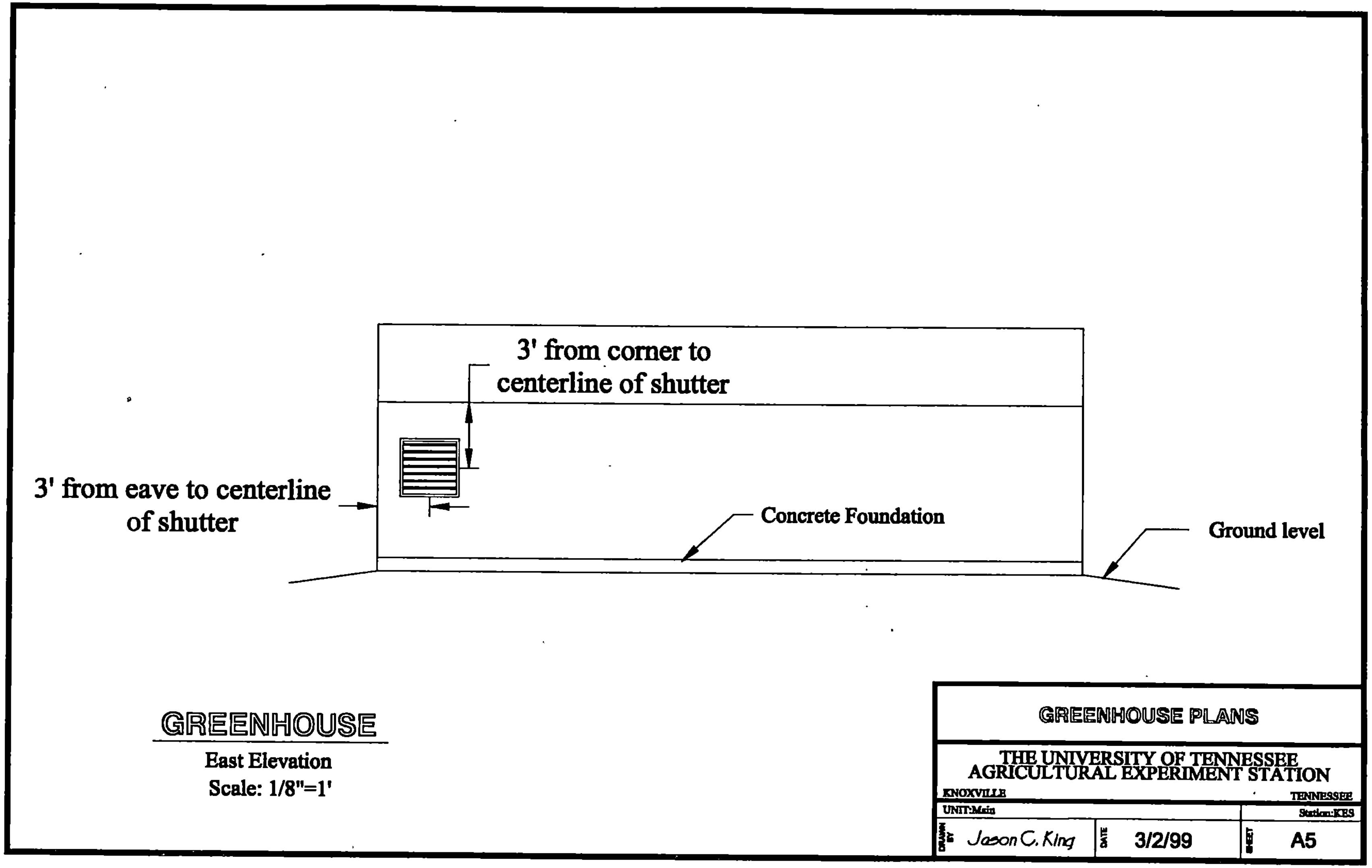

Figure B5. East elevation for greenhouse specifications.

VITA

Jason Carroll King was born on March 29, 1971 in Taipei, Taiwan. In 1989 he graduated from George Walton High School in Marietta, Georgia. In the fall of 1989, he entered Clemson University with a major in architecture. In 1993 he was awarded a Bachelor of Science degree in design.

After completing his bachelor's degree, the author married his Cheri Lynn Douglas and entered the ministry with Campus Crusade for Christ. He served as a campus minister at James Madison University in Harrisonburg, Virginia and as a customer service representative at the ministry's world headquarters in Orlando, Florida.

In 1997, he entered The University of Tennessee. In the spring of 1998, he was awarded a research assistantship in the Agricultural and Biosystems Engineering department. In December of 1998, he received a Master of Science degree in Biosystems Engineering Technology.