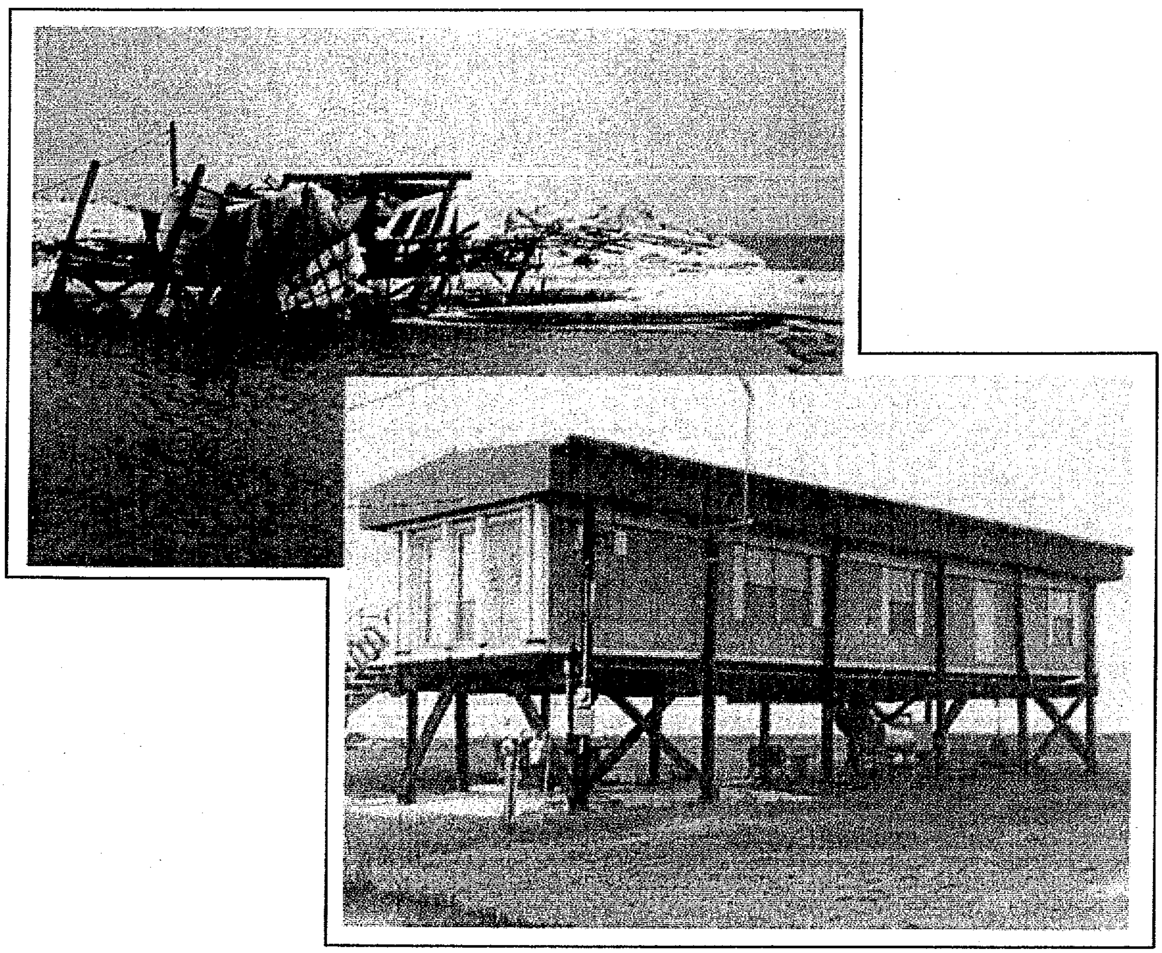
FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA 85 / September 1985

Manufactured Home Installation In Flood Hazard Areas



Manufactured Home Installation In Flood Hazard Areas

MANUFACTURED HOME INSTALLATION IN FLOOD HAZARD AREAS

FEDERAL EMERGENCY MANAGEMENT AGENCY

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INTRODUCTION

More than 10 million Americans live in manufactured homes. The 1980 Census revealed that almost four million occupied manufactured homes comprised over five percent of the nation's housing stock, and that two-thirds of the manufactured homes had been built and occupied since 1970. The increasing popularity of manufactured homes, coupled with their high vulnerability to the potential effects of flood and wind forces in flood hazard areas, has resulted in the need to apply special siting techniques for protecting manufactured homes in these areas.

This manual provides technical guidance on how to reduce the risk of flood damages to manufactured homes. As used in the context of this manual, the term "manufactured home" also includes those homes previously defined as "mobile homes." The information presented addresses techniques for elevating the manufactured home above anticipated flood levels and for adequately anchoring against flood and wind forces.

Application of these techniques will aid in reducing property loss and enhancing the safety of the manufactured home environment. Figures I.1, I.2, and I.3 highlight the importance of considering potential damage to manufactured homes in flood hazard areas.

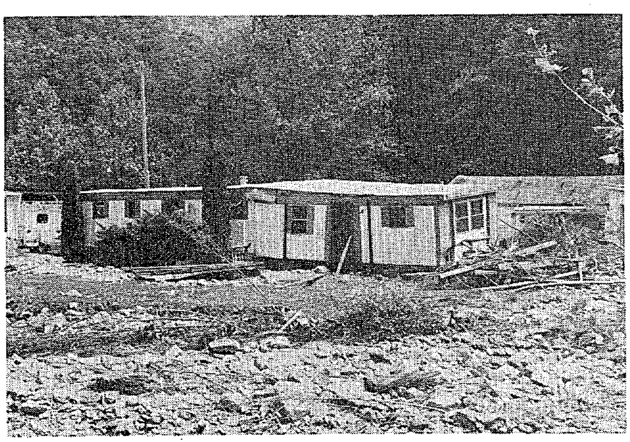


Figure I.1 Flood Damage

Figure I.1 shows complete devastation due to high velocity floodwaters and floating debris of a manufactured home installed without regard for site considerations and elevation.

Figure I.2 shows results of flotation and damage caused by inadequate anchorage and elevation.

Figure I.2 Flood Damage

Figure I.3 shows damage resulting from a lack of elevation and anchoring combined with structural damage from other floating manufactured homes.

Figure I.3 Flood Damage

The following is a brief description of the contents of the chapters of this manual, which are presented in a manner intended to parallel the decision-making process in siting a manufactured home in a flood hazard area.

CHAPTER I - OVERVIEW

A general background on manufactured homes, typical siting practices, discussion of flooding and its effects on manufactured homes, and an overview of the regulatory and building code requirements for manufactured homes.

CHAPTER II - FLOOD AND WIND HAZARDS

A presentation of flood and wind characteristics and their effects on manufactured homes.

CHAPTER III - ELEVATION AND ANCHORING TECHNIQUES

An overview of the various elevation and anchoring techniques that are applicable to the installation of manufactured homes in flood hazard areas.

CHAPTER IV - DESIGN OF ELEVATED FOUNDATIONS

Design criteria and calculations to be used in evaluating and selecting various elevating and anchoring techniques. Included are data, tables, mathematical formulas for design computations, and example problems.

CHAPTER V - COST ANALYSIS

Information on the cost of elevating and anchoring a manufactured home.

Using this approach, the manual provides necessary information for evaluating flood damage potential, determining the technical feasibility of design options, and selecting an installation technique that is both cost effective and technically sound. The ultimate goal is to reduce or eliminate damage potential for manufactured homes sited in flood hazard areas.

To provide assistance for users of the manual, a design worksheet is included.

Figure I.4 shows the regulations of the National Flood Insurance Program (NFIP), which is discussed in Chapter I. The NFIP provides performance standards for new manufactured home siting in flood hazard areas.

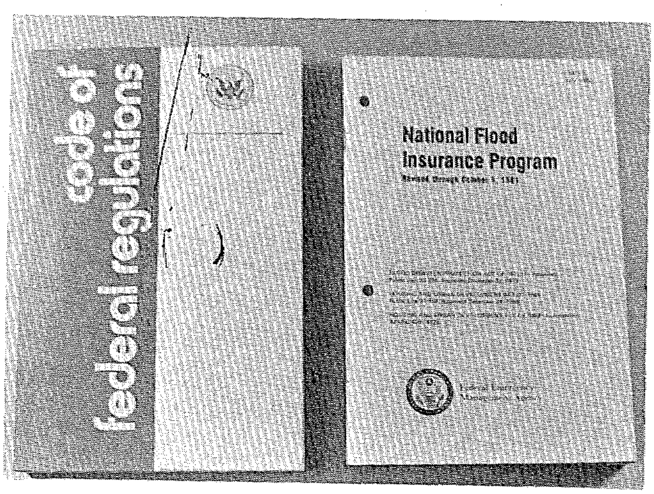


Figure I.4 NFIP Regulations

The technical criteria contained in this manual can be used to comply with the NFIP performance standards. Other federal regulations and programs affecting manufactured housing installation, such as those of the U. S. Department of Housing and Urban Development (HUD) for manufactured homes on permanent foundations, are not addressed in this manual or by the NFIP.

CHAPTER I

OVERVIEW

MANUFACTURED HOME CHARACTERISTICS

A manufactured home is a structure, transportable in one or more sections, that is built on a permanent chassis and is designed to be used with or without a permanent foundation when connected to required utilities.

Figure 1.1 shows a sectional view of a manufactured home.

The chassis consists of the undercarriage, wheel assembly, and towing hitch assembly. The floor joists are structural members of the chassis. Two longitudinal I-beams complete the chassis/floor system, as shown in Figure 1.2.

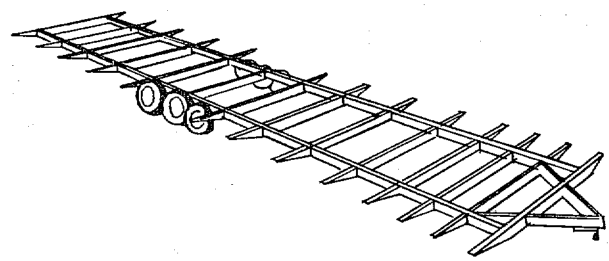


Figure 1.2 Chassis/Floor System

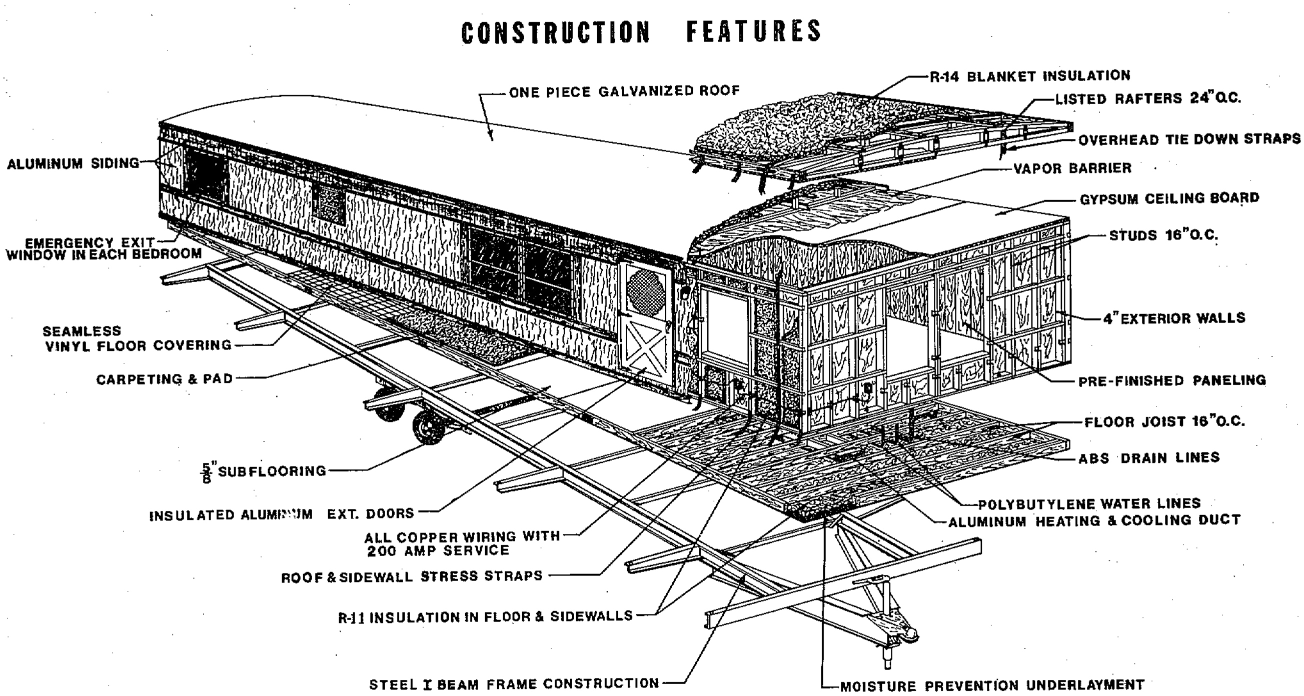


Figure 1.1 Manufactured Home

Some manufactured homes are designed for removal of the steel chassis when the manufactured home is placed on a permanent basement type foundation.

The longitudinal I-beams are the main supporting members for a manufactured home placed on an elevated foundation, as shown in Figure 1.3. The standard I-beam spacings are 75 1/2-, 82-, or 99-inches.

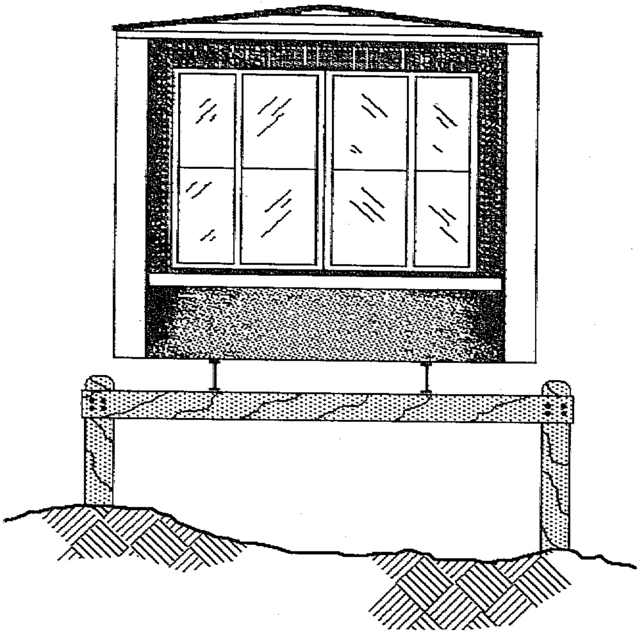


Figure 1.3 I-Beams

The floor decking material, which is attached to the floor joists, is usually wood particle board or plywood. The manufactured home walls are constructed using wood studs with the exterior of the

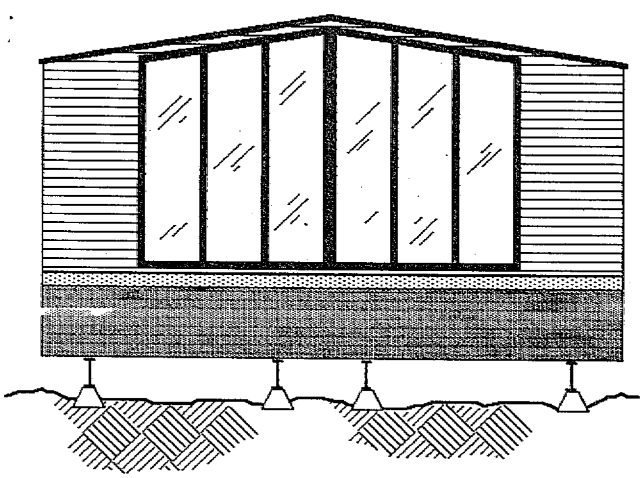


Figure 1.4 Double Section

home generally of aluminum or wood siding. The roof/ceiling system is constructed using prefabricated roof trusses and a metal or wood/shingle exterior. The manufactured home mechanical and electrical system is completely built into the manufactured home during construction. Installation of the manufactured home requires placement on a foundation system and connection to the required utilities.

A double section, as shown in Figures 1.4 and 1.5, refers to a manufactured home that is generally twice as wide as the normal 12 or 14 foot wide single unit.

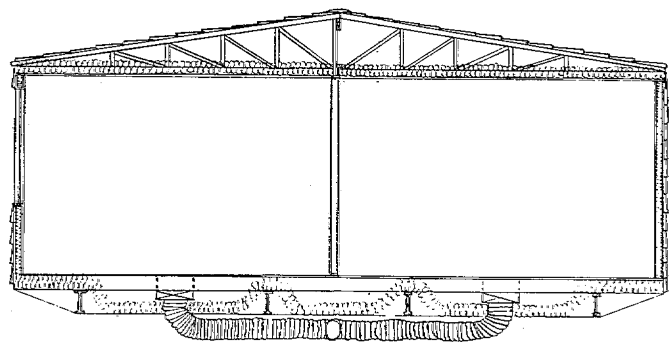
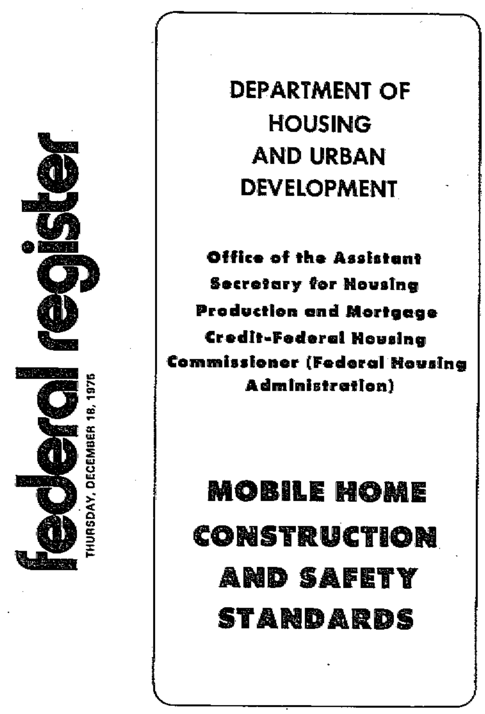


Figure 1.5 Double Section

The design and construction of the chassis/floor system is comparable to the single section unit. Transported in two sections, the units are joined at the site on a foundation similar to those used for single section units.

The design and construction of manufactured homes are controlled through regulations of the U. S. Department of Housing and Urban Development (HUD), shown in Figure 1.6.



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THURSDAY, DECEMBER 18, 1975

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Office of the Assistant Secretary for Housing Production and Mortgage Credit-Federal Housing Commissioner (Federal Housing Administration)

MOBILE HOME CONSTRUCTION AND SAFETY STANDARDS

Figure 1.6 HUD Regulations

The Manufactured Home Construction and Safety Standards (MHCSS) (24 CFR, Part 3280) establish performance requirements for the design of manufactured homes. A manufactured home designed and constructed in accordance with these standards will have a two- by four-inch aluminum plate label, as shown in Figure 1.7, located on the lower left side when viewing the tail light end of the manufactured home.

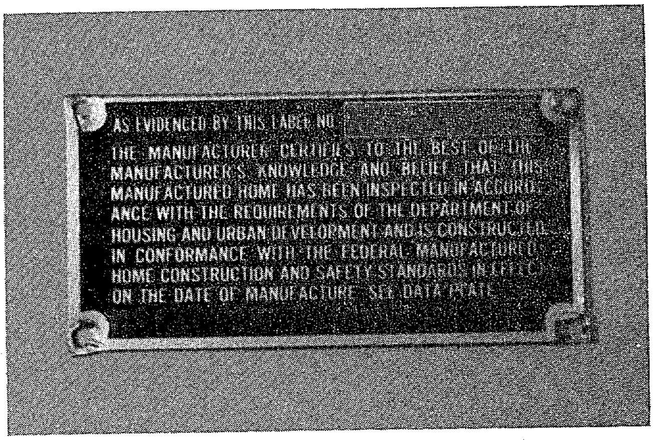


Figure 1.7 HUD Label Plate

CONVENTIONAL MANUFACTURED HOME INSTALLATION TECHNIQUES

Siting and installation requirements for manufactured homes are generally a state or local regulatory responsibility and are not within the scope of the MHCSS. The MHCSS do, however, require that installation instructions be incorporated into the owner's manual supplied with each new manufactured home. This is to assure that the purchaser has the correct procedures available for installing the manufactured home. A typical owner's manual is shown in Figure 1.8 and will be available for all manufactured homes constructed under the HUD Regulations.

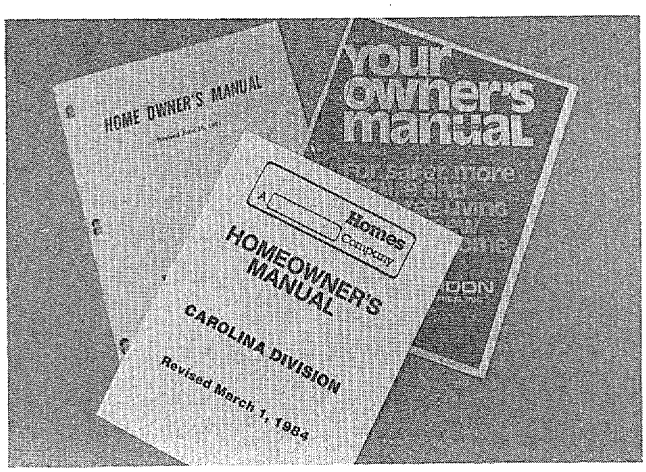


Figure 1.8 Manufactured Home Owner's Manual

In addition, the American National Standards Institute's (ANSI) Standard A225.1-1982, "Manufactured Home Installations,' shown in Figure 1.9, provides installation criteria applicable to many areas of the country.

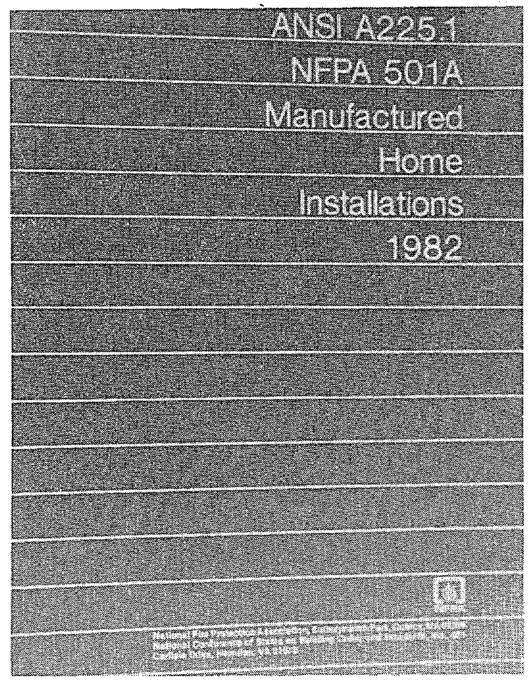


Figure 1.9 ANSI Standard

It is important to recognize that the installation procedures included in both the owner's manual and ANSI Standard A225.1-1982 are *not* considered to be adequate in cases where flood forces are anticipated.

The Manufactured Housing Institute estimates over half of the manufactured homes in use are sited on individually owned lots with the remainder in manufactured home rental communities. In a manufactured home community, shown in Figure 1.10, a rental fee is usually charged to cover the cost of land, required utility hookups, access roads, parking, and community facilities.

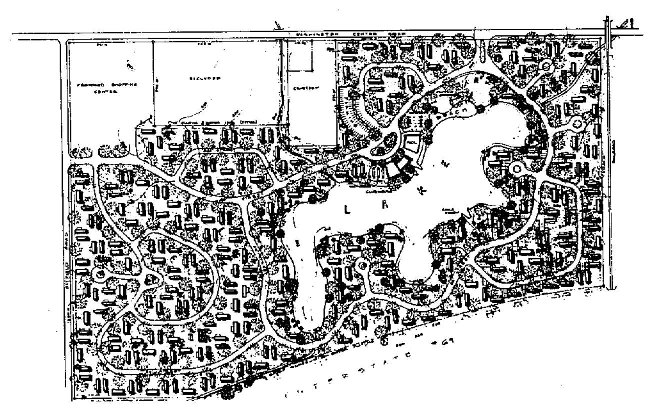


Figure 1.10 Manufactured Home Development

Modern developments provide paved sidewalks and streets, underground utilities, off-street parking and street lighting, park areas, playgrounds, and other recreational facilities. In some manufactured home communities the individual lot, in addition to the home, may be owned by the manufactured home owner.

A manufactured home is normally placed on a prepared site that has been stabilized and improved to provide adequate support for the manufactured home and anchoring system. The type of site and area improvements vary widely across the country and include simple ground stabilization, application of gravel, concrete runner or slab, concrete block piers, or more elaborate foundation construction. Because installation must allow for the wheels and axles upon which the manufactured home is transported and also for utility connections, the manufactured home is generally placed 24- to 36-inches above the ground. Since the steel frame and joists will generally be 14- to 20-inches in height, the finished floor of the manufactured home may be as high as 56 inches above grade.

For aesthetic reasons and improved access, it is sometimes desirable to employ a "low profile" siting in which the site area is excavated below grade as shown in Figure 1.11.

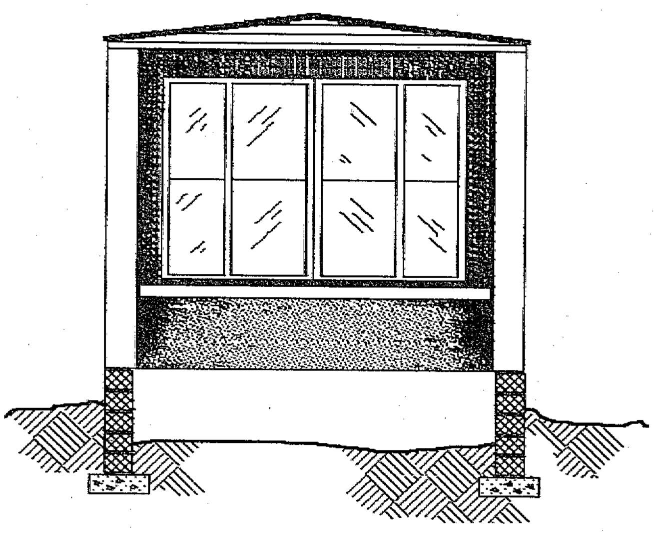


Figure 1.11 Low Profile Siting

This technique requires special provisions for adequate drainage and ventilation.

A typical manufactured home installation, as shown in Figure 1.12, involves supporting the manufactured home by piers (concrete masonry blocks resting on a small concrete footing) placed typically every eight to ten feet of length beneath the two chassis I-beams.

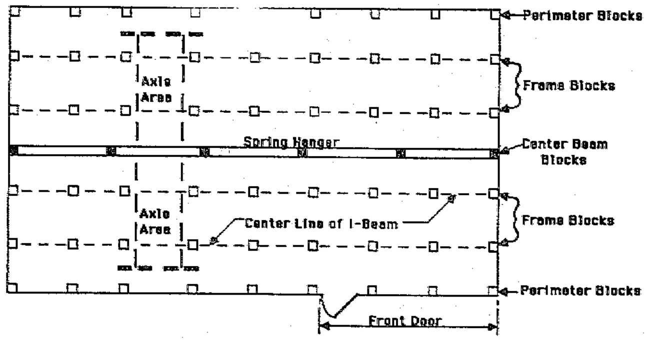


Figure 1.12 Conventional Installation

Ground anchors, which are located under the manufactured home, are secured to the manufactured home with frame ties connected to the chassis I-beams, and where acceptable from a design standpoint, over- the-top ties. Figures 1.13 and 1.14 show typical manufactured home installation techniques.

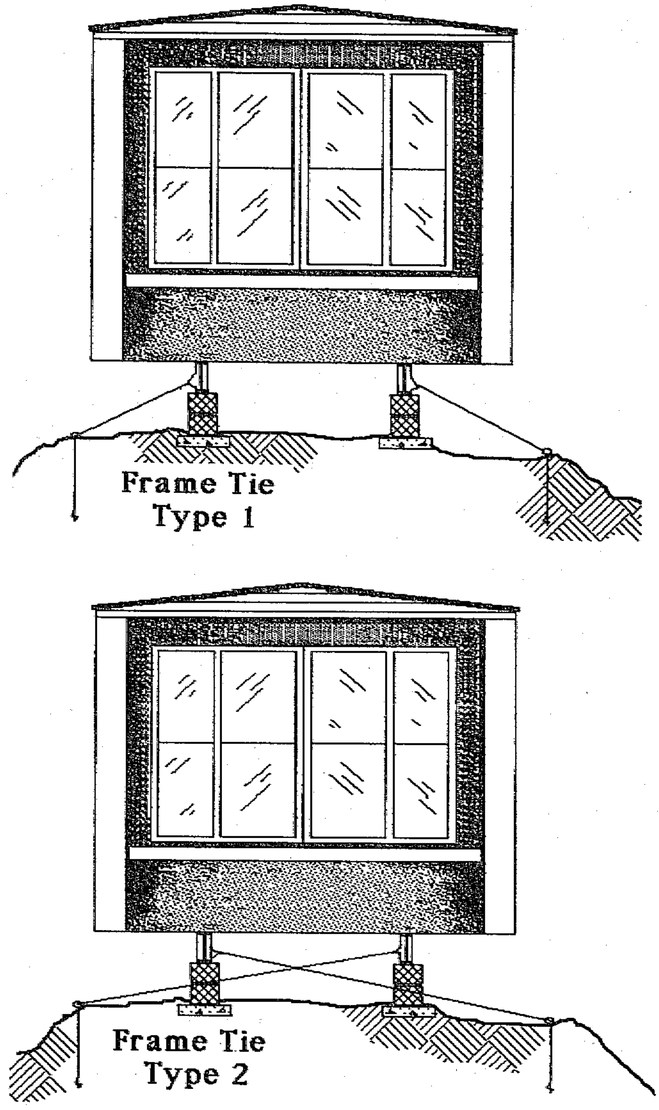


Figure 1.13 Tie-Down Systems

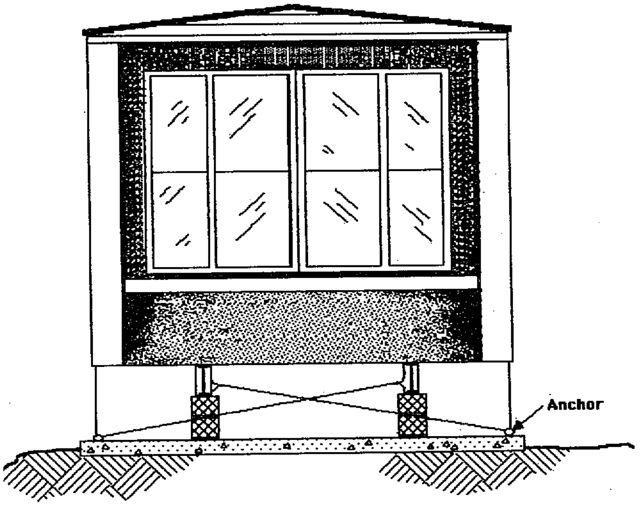


Figure 1.14 Tie-Down System

It should be emphasized that conventional installation described above would rarely be adequate for resisting the flood forces that can be expected in areas prone to flooding. A manufactured home that is elevated a few feet above the ground and anchored to resist wind forces will still be vulnerable to the additional forces produced by flooding. Movement of the home from the foundation supports, inundation, or both can result in major damage, as shown in Figure 1.15.

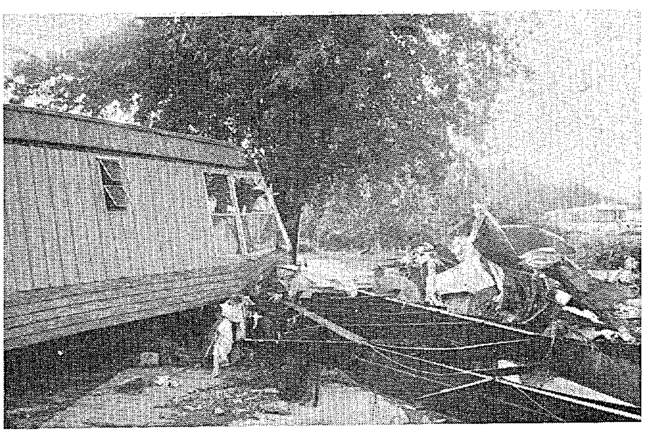


Figure 1.15 Movement From Foundation

Even relatively minor inundation can cause significant damage to a manufactured home as shown in Figure 1.16. For example, a water level of only two feet above the floor can potentially cause damage equivalent to approximately 80 percent of the value of the home.

In flood hazard areas, additional elevation and flood and wind load considerations may necessitate a siting technique that varies substantially from conventional installation methods.

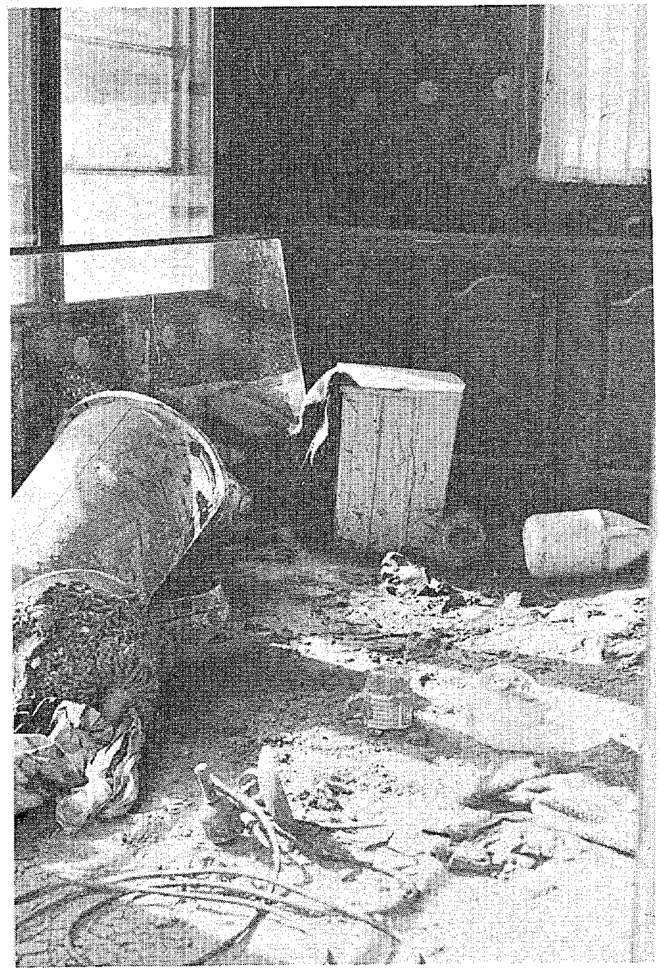


Figure 1.16 Inundation Damage

Depending upon the characteristics of the flooding anticipated, the home may be elevated using piers, posts, pilings, or fill. The use of an elevated foundation will differ from a normal siting technique in terms of the desired height above grade and the structural capacity of the elevating system to withstand anticipated flood and wind loads. Figures 1.17 and 1.18 show elevating techniques.

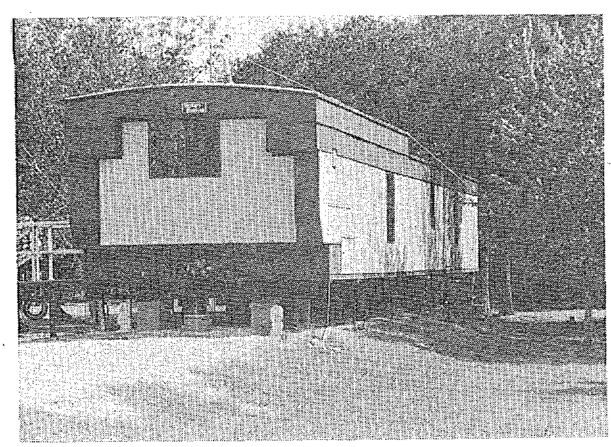


Figure 1.17 Elevation Using Fill

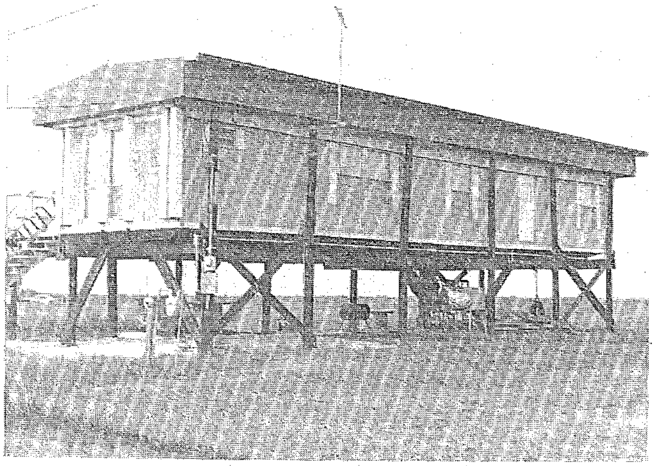


Figure 1.18 Elevation Using Wood Foundation

Elevating alternatives and related anchoring techniques are presented in detail in Chapter III.

EFFECTS OF FLOODING ON MANUFACTURED HOMES

Manufactured homes in flood hazard areas may be affected by a variety of conditions that vary in intensity from site to site. Flood forces and parameters are presented in detail in chapter two of the manual. The following provides an introductory overview of the types of flooding and their effects on manufactured homes which are installed using the conventional set-up techniques discussed above.

There are two general flooding types—riverine and coastal. Each environment exhibits physiographic features that determine the magnitude, duration, and frequency of floods. Flood characteristics, especially the significant parameters of depth and velocity, produce conditions that can adversely affect manufactured homes, as shown in Figure 1.19.

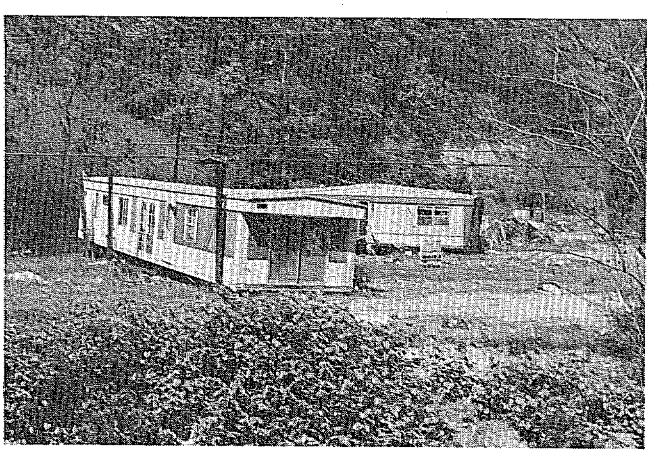


Figure 1.19 Flood Damage

These include inundation with water, uplift and movement of the manufactured home from its foundation, and debris impact on the foundation and manufactured home.

Riverine Flooding—A region's watershed, shown in Figure 1.20, is the natural drainage basin that conveys water runoff. Water that is not absorbed by the soil and vegetation becomes surface water runoff, seeking the natural drainage lines according to local topography.

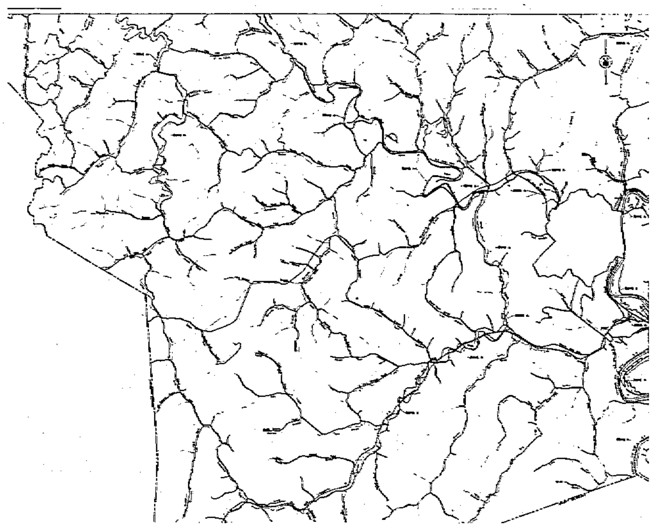


Figure 1.20 Watershed

These lines merge to form a hierarchical system of streams that includes swales for drainage channels, creeks, and rivers, each of successively larger capacity.

The primary element of a stream is the channel, which carries the normal flow of water. The area of flat or gently sloping land adjacent to the channel, as shown in Figure 1.21, is the floodplain.

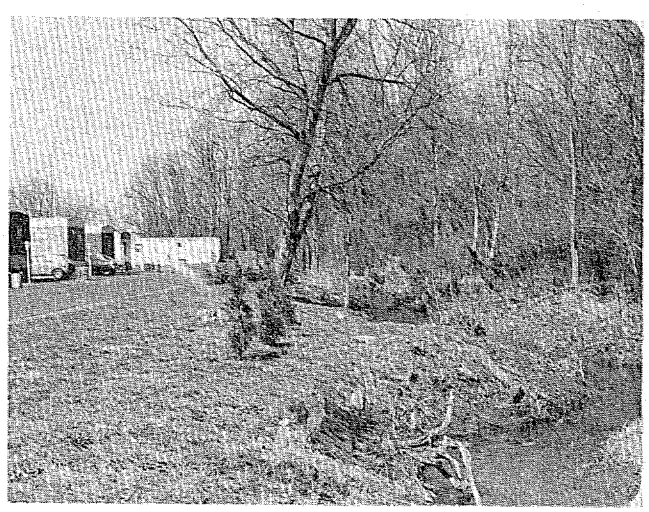


Figure 1.21 Floodplain

Flooding usually involves a build-up of water in the channel followed by overflow that inundates the floodplain. Generally, the rise in water surface elevation is slow in large streams and more rapid in small streams.

Several types of riverine flooding occur, each posing specific threats to manufactured homes.

Flash flooding involves an extremely fast rise in water surface elevation and abnormally high water velocity, often creating a "wall" of water and debris moving down the channel and floodplain.

Flash floods usually result from some combination of intense precipitation, steep slopes, a small drainage basin, and a high proportion of impervious ground surfaces. They often occur in small streams that are normally shallow or dry and can cause extensive damage as shown in Figure 1.22.

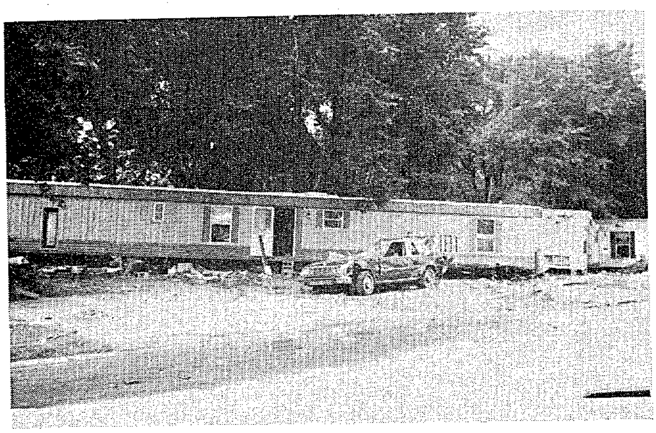


Figure 1.22 Flash Flood Damage

The high water velocity characteristic of flash floods can significantly affect manufactured homes in terms of erosion or scour around the foundation, movement of the manufactured home off the foundation, and impact on the manufactured home by debris carried in the floodwaters. Although inundation is always a concern, damage sustained from a flash flood event will generally depend upon the strength of the foundation and anchoring system to resist movement of the manufactured home. Even in situations where floodwaters do not reach the floor of the manufactured home, the foundation and anchoring systems will have to resist high water velocity and debris impact forces. If these systems are not properly designed and installed, failure resulting in foundation collapse and manufactured home inundation will most likely occur, as shown in Figure 1.23.

When greater flood depths are experienced, inundation of the manufactured home is likely to occur, and the forces on the foundation and anchoring systems are subsequently intensified.

Shallow flooding includes unconfined flows over broad, relatively low areas; intermittent flows in

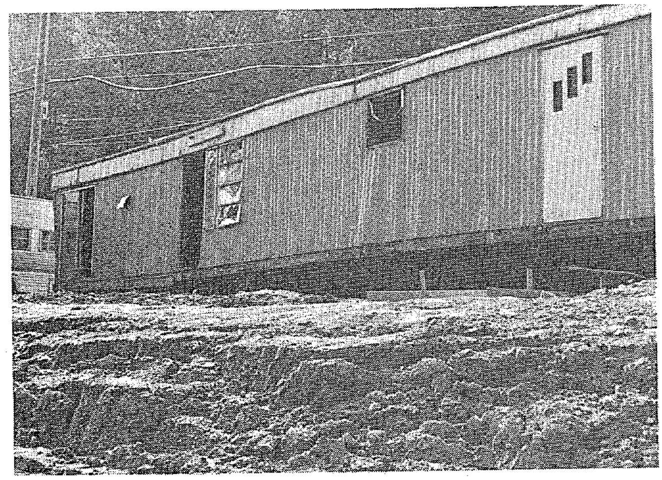


Figure 1.23 Flash Flood Damage

arid or semi-arid regions that have not developed a system of well-defined channels; minor stream bank flows that remain unconfined; overland runoff in dense urban areas; flows where heavy debris deposits cause constantly shifting channels; and "ponding" in topographic depressions. Flow direction is extremely difficult to predict. Generally, shallow flooding areas are considered as those areas exhibiting depths of three feet or less. A conventional manufactured home installation may provide adequate elevation during a shallow flooding occurrence. A cautionary statement is appropriate, however, calling attention to the substantial damage that can be caused by a relatively small amount of water within the manufactured home. The aforementioned flood loads applied to the foundation and anchoring systems can also be applicable to shallow flooding circumstances. Even very shallow floodwater can have high velocity sufficient to cause erosion, scour, and subsequent failure of the foundation system, as shown in Figure 1.24.

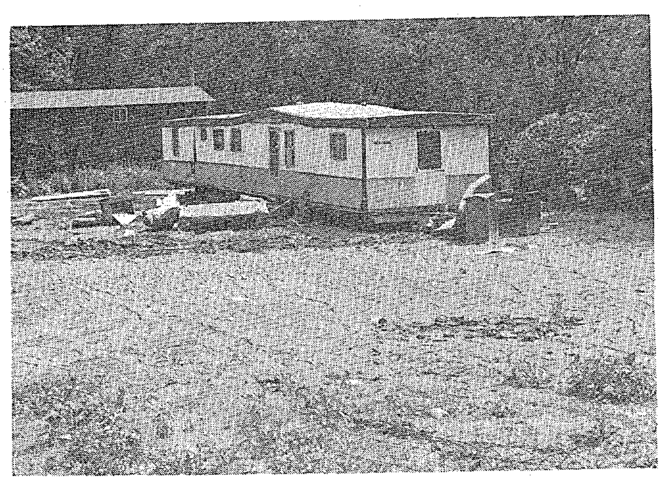


Figure 1.24 Shallow Flooding Damage

Floodwaters need not be deep or fast to affect the integrity of an anchoring system. Soil saturation occurring during periods of prolonged flooding can reduce the holding capacity of ground anchors causing them to pull out as shown in Figure 1.25.

Figure 1.25 Failed Ground Anchor

Deep flooding accentuates the forces acting upon the foundation and anchoring systems of a manufactured home. In addition, increased flood depths affect a non-elevated manufactured home by directly transferring forces to the walls and floor. The initial imbalance of water levels between the exterior and interior of the manufactured home will likely result in buoyancy. This uplift force can completely dislodge an inadequately anchored manufactured home from its foundation. This typically occurs in fast rising waters or when the rate-of-rise of floodwaters is very fast.

In situations where the rate-of-rise of floodwaters is slow, allowing the manufactured home to fill with water and therefore counteracting the buoyancy forces, or where adequate anchoring is employed to resist dislodging the manufactured home from its foundation, deep flooding can substantially damage a non-elevated manufactured home by direct inundation. Although the manufactured home may remain in place, as shown in Figure 1.26, it will likely be a total loss due to the damage caused by water inundation.

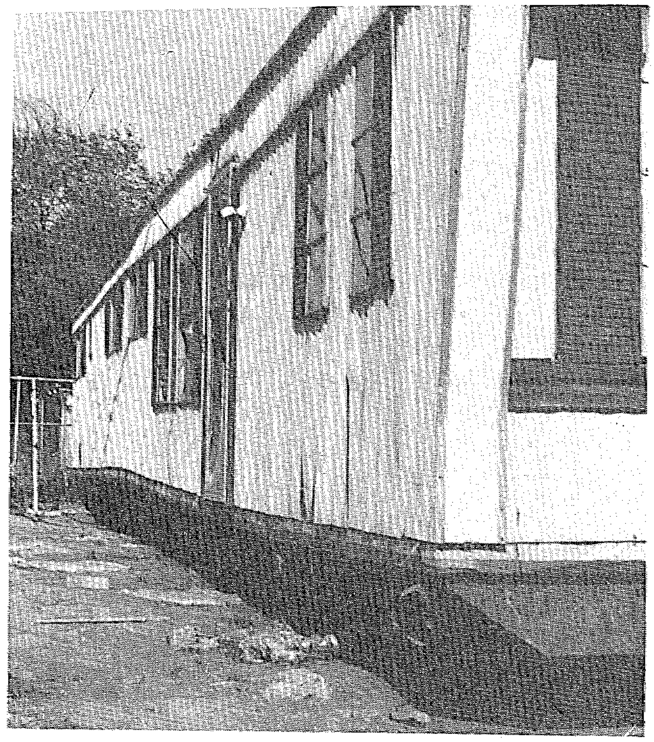


Figure 1.26 Deep Flooding Damage

In addition to having high erosion and scour potential, deep velocity flooding also emphasizes the need to consider debris impact potential.

Coastal Flooding—Coastal flooding is generally due to ocean-based storm systems. Hurricanes, tropical storms, and extratropical storms, such as "northeasters," are the principal causes, with flooding occurring when storm tides are much higher than the normal tide. This is a "storm surge" and exhibits high water velocity and wave action. The maximum intensity of a storm tide occurs at high tide, so storms that persist through several tide cycles, such as "northeasters," are the most severe.

The velocity and range of coastal floods vary in part with the severity of the storm of which they are a part. The damaging effects of coastal flooding are caused by a combination of the storm surge, rain, wind, waves, erosion, and battering by debris.

The extent and nature of coastal flooding is also related to physiographic features of the terrain and the characteristics of the adjoining body of water. Pacific coastal areas are principally vulnerable to earthquakes, tsunamis (seismically induced tidal waves) and other natural forces that can trigger excessive erosion, mud slides, and flash flooding. Great Lakes coastal areas are subject to erosion and severe winter storms. The Atlantic and Gulf Coasts are consistently exposed to the forces of hurricanes, lesser tropical storms, and northeasters.

Coastal flooding is most frequent on the Atlantic and Gulf Coasts, which are made up of a succession of barrier islands, beaches, and dunes. These physiographic elements are maintained in dynamic balance as sand is moved by wind, waves, and ocean currents. This self- replenishing beach-dune system resists storm surges and provides a buffer for inland areas.

In coastal areas, as shown in Figure 1.27, the removal of beach sand and the leveling of dunes, along with the construction of seawalls, jetties, and piers, are common practice. These can destroy the shoreline's natural protection system, further increasing the impacts of surges and high winds.

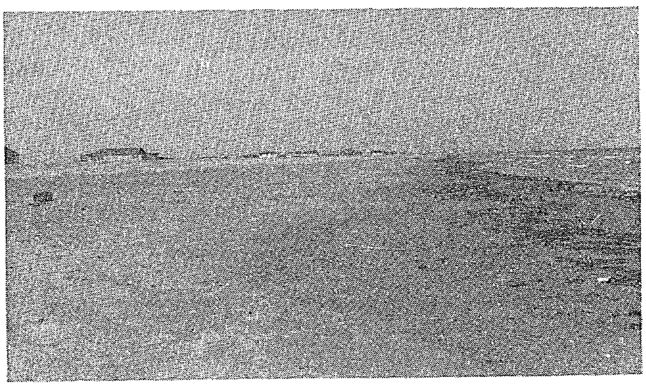


Figure 1.27 Coastal Area

Manufactured homes in coastal flood hazard areas, as shown in Figure 1.28, are subject to the same flood forces experienced in riverine flooding environments. However, in some cases, the coastal forces occur at greater magnitude and severity.

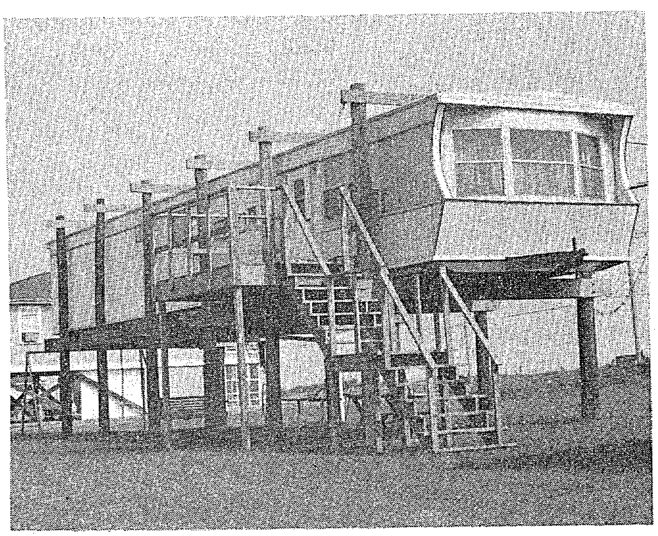


Figure 1.28 Elevation in Coastal Zone

Coastal areas represent a unique hazard to the typical manufactured home installation due to the potential for very high forces from velocity water and wave action. These factors, combined with the potential for scour and erosion and high debris impact forces, represent a significant hazard to the typical manufactured home set-up. The susceptibility of coastal areas to extremely high winds presents additional hazards to manufactured homes sited in this environment, as shown in Figure 1.29.

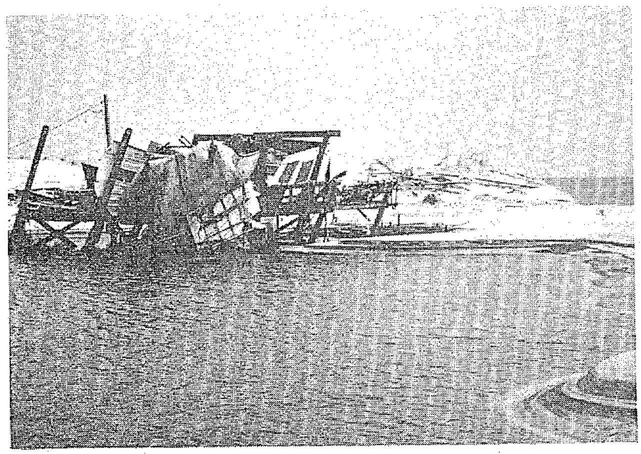


Figure 1.29 Wind Damage

In the coastal environment, the combined effects of flood and wind forces must be evaluated to determine adequate anchoring and elevating techniques. Subsequent chapters of the manual will address the impact of flood and wind forces on manufactured homes.

REGULATORY REQUIREMENTS

As an initial step in the installation of a manufactured home in a flood hazard area, federal, state, and local regulatory requirements must be identified and assessed. Much information regarding flood hazards and construction in flood-prone areas is available through a wide variety of public agencies at all levels of government (see Appendix C).

Federal Regulations—The National Flood Insurance Program (NFIP) is the Federal Government's principal administrative mechanism for reducing flood losses. Established by Congress in 1968 and broadened and modified since then, the NFIP is administered by the Federal Insurance Administration (FIA) of the Federal Emergency Management Agency (FEMA). The program offers property insurance for buildings and their contents in flood-prone areas where conventional insurance had been generally unavailable.

The NFIP provides insurance to communities that agree to implement comprehensive land use planning and management to reduce flood damage in their jurisdictions. Community response to this requirement generally involves the adoption of zoning, building code, and other development regulations that place various requirements on new construction and on substantial improvements to existing construction in identified flood hazard areas. Some communities, either in recognition of the benefits of a strong floodplain management program or in response to specific problems, adopt regulations that are considerably more restrictive than the minimum NFIP requirements.

FEMA establishes "Special Flood Hazard Areas" that depict those areas inundated by the 100-year flood as shown in Figure 1.30.

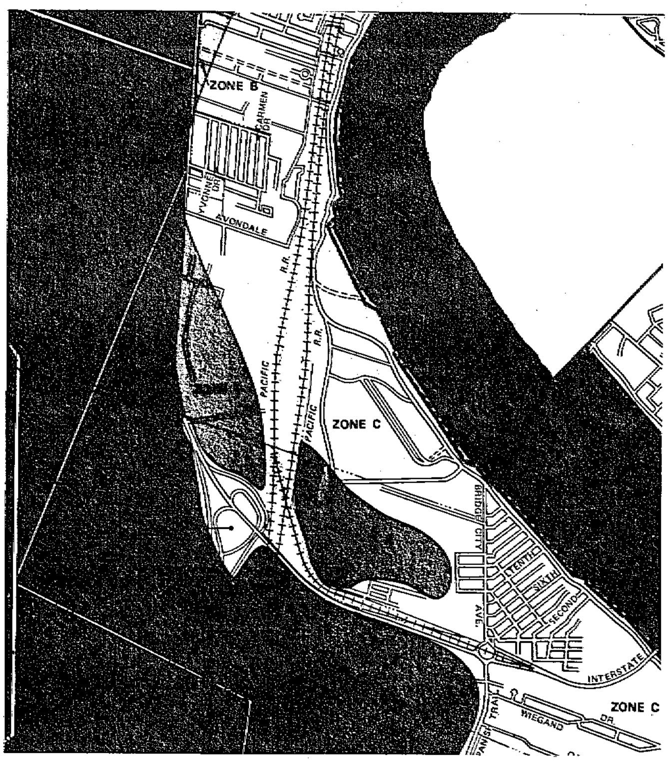


Figure 1.30 Special Flood Hazard Areas

This "base flood" is a flood that has a one percent chance of being equalled or exceeded in any given year. Over a 30-year period, there is at least a 26 percent chance that this flood will occur.

The 100-year flood standard is used by every federal agency in their administration of flood-related programs. This standard has also been adopted by many states and is used administratively in the operations of their own programs involving floodplain management.

The NFIP's flood insurance premium structure has been developed based upon studies of the degree of property exposure to flood hazards. Flood hazard areas are divided into different zones according to the degree of risk. The insurance rates vary according to the zone and, in certain cases, to the elevation of the building in relation to the base flood. Higher rates are charged for buildings subject to greater hazard. This differential rate structure provides a financial incentive for homeowners to reduce their susceptibility to flood damage.

The NFIP is administered in two phases: the Emergency Program and the Regular Program.

The function of the Emergency Program is to make flood insurance readily available to property owners throughout flood-prone communities. The operation of the program is simple and direct. The FIA notifies a community that it has been identified as flood prone by providing the community with a Flood Hazard Boundary Map (FHBM), as shown in Figure 1.31.

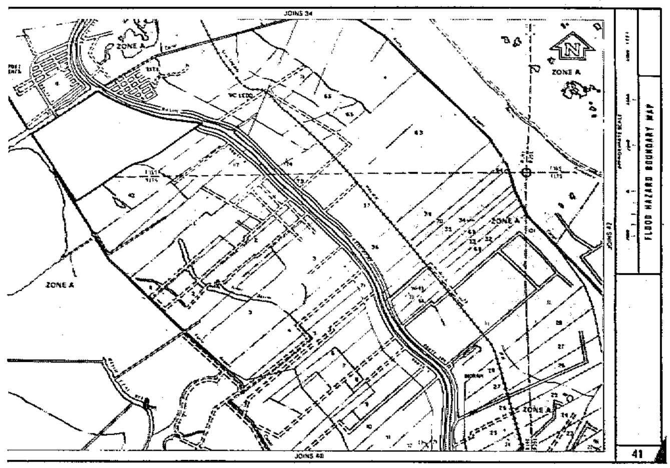


Figure 1.31 Flood Hazard Boundary Map

This map is a preliminary delineation of special flood hazard areas within the community with a definite likelihood of inundation. No elevations are shown.

A community receiving such a map may participate in the program by completing an application to FIA. Upon approval of the application, limited amounts of insurance become available in that community. The community is required to apply minimal floodplain management regulations based on the FHBM and is encouraged to reasonably use any additional data that may be available from other sources to establish the flood elevations.

A community generally enters the Regular Program after the completion of a detailed technical study of flood hazards. The study includes a determination of elevations of floods of varying intensity, including the base flood, areas inundated by the various magnitude of flooding, and flood boundaries. This information is presented on a Flood Insurance Rate Map (FIRM) and Flood Boundary and Floodway Map (FBFM), as shown in Figures 1.32 and 1.33.

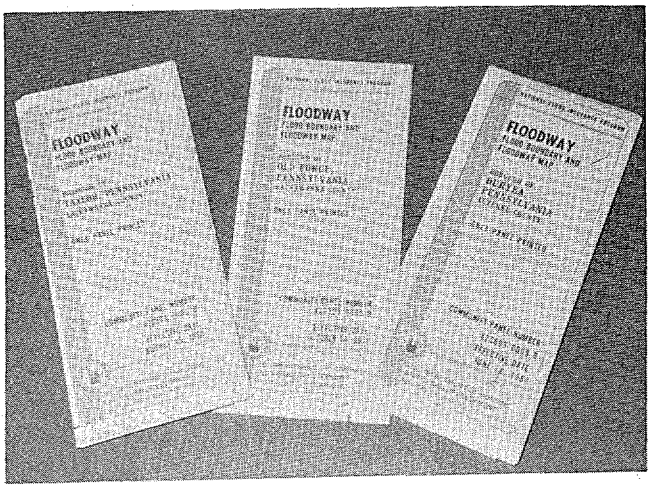


Figure 1.32 Flood Insurance Rate Map

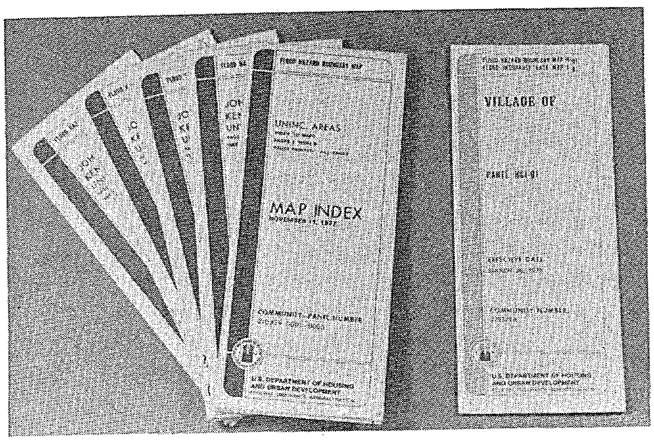


Figure 1.33 Flood Boundary and Floodway Map

FIRMs generally show flood-prone areas as either A-Zones or V-Zones. Riverine flood-prone areas and coastal flood-prone areas subject to storm surges with velocity waves of less than three feet during the 100-year flood are generally classed as A-Zones. "Coastal high hazard areas" are shown on FIRM's as V-Zones. The V-Zone is the portion of the floodplain subject to storm surges with velocity waves of three feet or more during the 100-year flood.

Based on this information, regulatory standards that are more detailed than Emergency Program requirements are adopted and enforced by the participating community. These standards include requirements that influence the location and manner of installation of manufactured homes.

The technical guidelines contained in this manual can be used in complying with the NFIP performance standards. Also, local community officials should be contacted to determine what NFIP regulations govern the placement of manufactured homes in flood hazard areas.

State and Local Regulations—Some states have regulations, as shown in Figure 1.34, applying to the placement of manufactured homes in flood hazard areas.

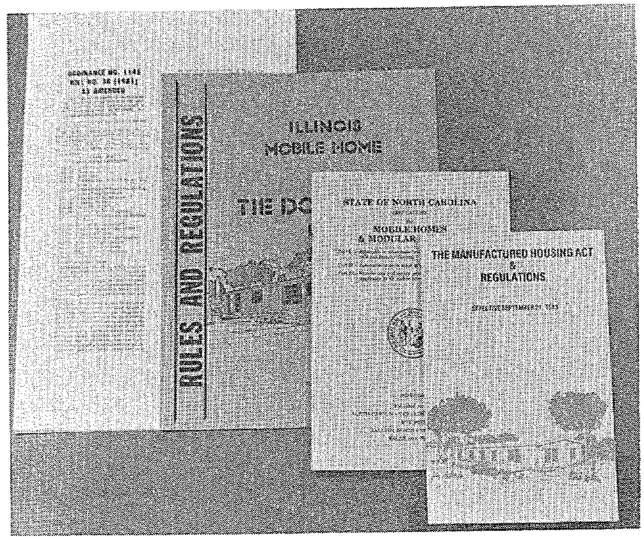


Figure 1.34 State and Local Regulations

New Mexico, for example, requires manufactured home dealers to provide the purchaser with a notice to check with the local government to determine installation requirements in a flood hazard area. In Texas, North Carolina, and several other states, when more than one-fourth of the manufactured home frame members are more than three feet above grade, the foundation system must be designed by a registered professional engineer or architect.

The appropriate state government departments responsible for manufactured housing installation, floodplain management, water resources, building codes, or coastal zone management should be consulted prior to installation of a manufactured home in a flood hazard area.

Each state also has designated a state coordinating agency to assist in the implementation of the NFIP. This agency is a focal point for information on flood insurance, floodplain management, and coordination of the diverse state agencies with responsibilities for riverine and coastal floodplains. A listing of state coordinating agencies is included in Appendix B.

The authority of each state's coordinating agency varies and can best be determined through direct contact. These agencies can be important sources of physical data, information on community eligibility for flood insurance, state regulations, references to other agencies and, in some instances, technical assistance.

Local governments play the key role in floodplain management. Most local jurisdictions have specific zoning ordinances and regulations pertaining to manufactured homes and manufactured home developments. In addition, they can provide sources of flood hazard data and other regulatory information. Local offices that may be of assistance include Departments or Offices of Public Works, Building, Engineering, Zoning, and Planning.

Building Codes—Building codes can be a mechanism for reducing flood losses through the inclusion of sections specifically intended to mitigate flood damage.

The Building Officials and Code Administrators' (BOCA) Basic/National Building Code, the International Conference of Building Officials' (ICBO) Uniform Building Code, and the Southern Building Code Congress International's (SBCCI) Standard Building Code, shown in Figure 1.35, all include sections requiring structural integrity of foundations, walls, floor slabs, and retaining walls that may be subjected to flooding.

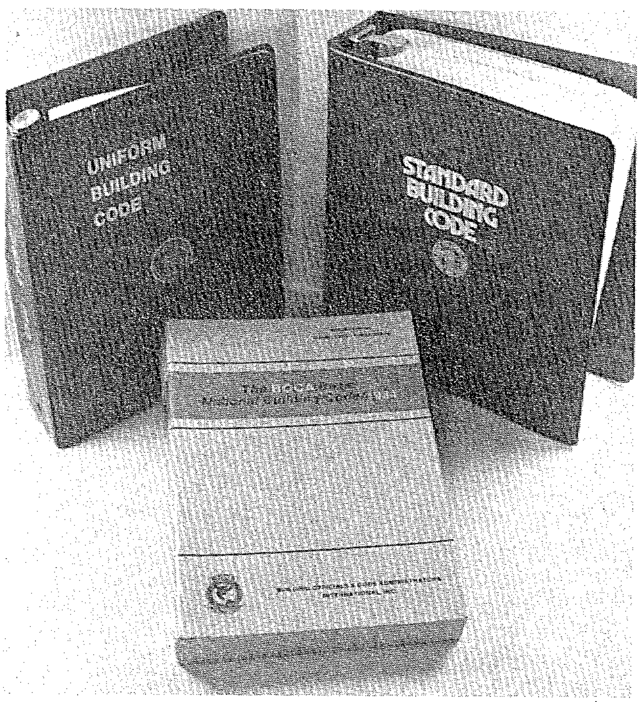


Figure 1.35 Building Codes

These model codes are used in many parts of the country and are developed with technical data from many organizations and individuals through an annual code revision process. Some communities may have similar or more stringent requirements that specifically address manufactured homes. State and local guidance should be used to determine what flood-related codes are in effect for a particular area.

Chapter II describes the effects of flood and wind forces on manufactured homes.

FLOOD AND WIND HAZARDS

FLOOD AND WIND HAZARDS

Flooding and wind have various characteristics and parameters that determine the magnitude of forces produced by these natural hazards. Because a manufactured home installation can be affected by flood and wind induced forces acting on the body of the unit, the supporting foundation structure, and the anchoring system, these forces and their application to manufactured homes become critical and must be recognized.

HAZARDS FROM FLOODS

Flood Forces—Floodwaters cause pressures or forces on the surfaces of manufactured homes and their supporting foundations. These forces are of three basic types: hydrostatic, hydrodynamic, and debris impact.

Hydrostatic forces are caused by water either above or below the ground surface, free or confined, that is essentially stagnant. These forces result at any point of floodwater contact with a structure. Hydrostatic pressures are equal in all directions and always act perpendicular to the surface on which they are applied. As Figure 2.1 indicates, the loads can act vertically on structural members, such as floors and foundation slabs, and can act laterally on upright structural elements, such as walls, piers, piles, or posts.

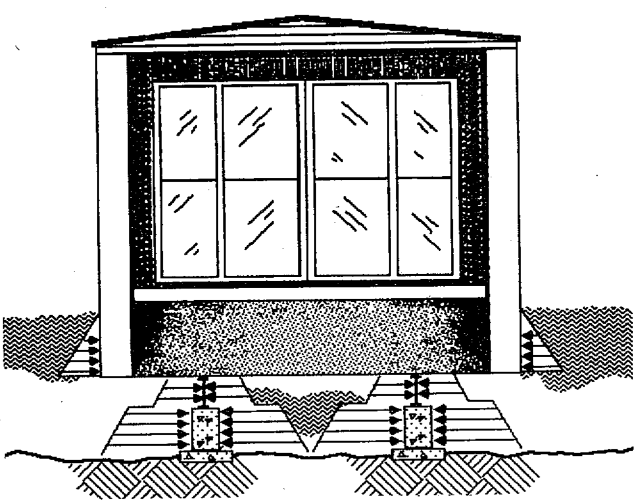


Figure 2.1 Hydrostatic Forces

Hydrostatic forces have the ability to cause manufactured home flotation, floor and wall collapse, and foundation/anchoring system failure.

Hydrodynamic forces, depicted in Figure 2.2, are those caused by the flow of floodwater around and against the manufactured home or foundation. Hydrodynamic forces are lateral in nature and apply directly against the structure. They include drag forces as water flows around the structure and negative pressure caused by eddies on the downstream side.

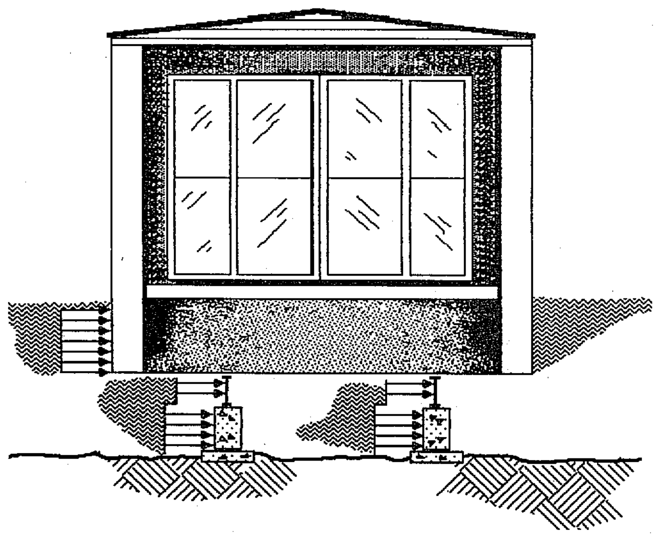


Figure 2.2 Hydrodynamic Forces

Hydrodynamic forces have the ability to cause foundation system failure, increase erosion and scour around foundation system components, and cause damage to the manufactured home structure, as shown in Figure 2.3.

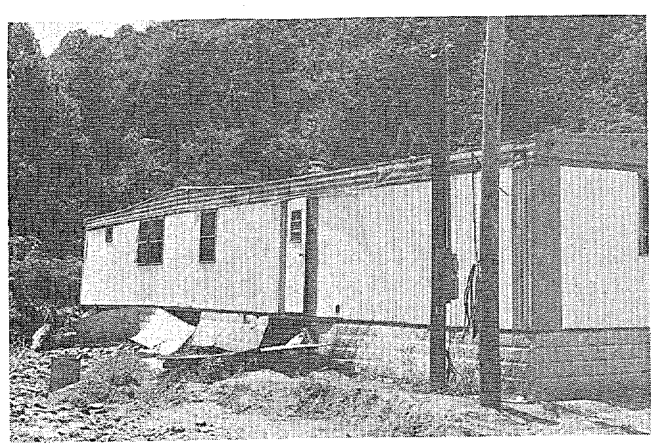


Figure 2.3 Damage From Hydrodynamic Forces

Debris Impact Force—Floods also present an additional hazard to structures by creating the potential for debris impact as shown in Figure 2.4. Debris impact forces are produced by solid objects carried by the floodwaters striking the structure. These forces are extremely difficult to predict and quantify with a high degree of accuracy, yet their effect on structures is significant enough to warrant consideration.

Figure 2.4 Damage From Debris

Debris impact forces include isolated objects of normally encountered sizes, such as logs; conglomerates of floatable objects, such as ice floats; and extremely large masses, such as a collapsed structure. Forces are produced by objects both striking and resting against a structure. For the purpose of design, assumptions on object weight and impact speed must be made. Chapter IV presents specifics on debris impact forces.

The magnitude of these three types of flood forces is dependent on several flood related parameters such as velocity, depth, duration, rate-of-rise, and frequency.

Flood Hazard Parameters—Flood hazard parameters are used to determine the degree of hazard that can be expected at a site and provide necessary information for evaluating and choosing damage reduction and site design strategies.

Depth of flooding is the difference between the water surface elevation at the time of flooding and the normal grade elevation of the flooded area. Flood depths determine the magnitude of the hydrostatic forces that act on a manufactured home. There is a direct relationship between depth of water and amount of hydrostatic pressure. Greater depths of water exert greater pressure on a structure. A water depth of five feet, for example, exerts 312 pounds of pressure per square foot of surface. This pressure can cause buoyancy, lateral displacement, and overturning of a manufactured home as well as structural damage to the floor and wall assemblies. In addition, depth of flooding is a very important consideration when elevating a manufactured home. A two foot depth of inundation can potentially result in damages up to about 80 percent of the value of the manufactured home.

The conventional manufactured home installation may provide adequate protection from inundation in some flooding situations, where depths of flooding do not exceed the 24- to 36-inch foundation height of the conventional installation.

In deeper flooding situations the height of the conventional manufactured home installation is exceeded. Once the floodwaters inundate any portion of the manufactured home, the probability of significant damage increases. In addition to damage resulting from inundation, differential water levels between the interior and exterior of the manufactured home result in uplift forces on the manufactured home. These forces can result in movement of the manufactured home off its foundation supports and cause other structural damage to the manufactured home. This situation can be expected where there is a rapid rate-of-rise of floodwaters resulting in insufficient time for the water to enter the manufactured home and counteract the buoyancy forces.

Velocity of flooding is the time rate of the linear motion of floodwaters usually measured in feet per second. Flood velocities vary from point to point in a floodplain and determine the magnitude of hydrodynamic forces affecting a manufactured home. Velocity floodwaters will result in significant lateral forces on the typical manufactured home installation. Lateral forces on the foundation supports, along with erosion and scour of the foundation, can result in failure of the foundation if improperly designed.

When flood depths exceed the foundation height, lateral forces from velocity floodwaters on the walls can move the manufactured home off its foundation supports, resulting in inundation and damage to the home. Conventional installation techniques are inadequate to withstand the amount of lateral force which can be expected from velocity floodwaters.

The potential for debris impact forces is also much greater in a velocity flooding situation, because the amount and size of debris will vary from location to location. The magnitude of the debris impact force upon a manufactured home or the foundation supporting the home is directly proportional to the velocity of the floodwater. Basic assumptions concerning the size of debris and velocity of impact must be made when designing a foundation in a high velocity flood-prone area.

The potential for scour and erosion of the foundation also increases with velocity. If scour and erosion are of concern, protection for the foundation or increasing the embedment of the foundation supports should be considered.

Rate-of-Rise is a measure of how rapidly water depths increase during flooding. A slow rise of floodwaters will allow seepage of water into a manufactured home thereby counteracting uplift forces.

When floodwaters rise quickly, this balance may not occur in time, resulting in buoyancy or failure of the manufactured home floor. Rate-of-rise is also relative to the amount of warning time prior to flooding. This is important in planning for emergency evacuation and in determining the feasibility of emergency loss mitigation procedures.

Duration of flooding is the amount of time from inundation of an area to the recession of floodwaters. Duration influences how long the manufactured home and its foundation will be subject to hydrostatic and hydrodynamic pressures, the strength of soils and building materials, the degree of seepage, and the length of time that a structure may be inaccessible.

Frequency of flooding, the rate of recurrence of floods at a particular location, is primarily a consideration in selecting the installation site. Repeated occurrences of flooding over time, even when a single event does not result in the total loss of a manufactured home, can produce a cumulative wear-and-tear effect on a typical installation. Flood frequency data is useful in the design of foundation and elevating systems in that it is an essential element in formulating assumptions as to how often these systems will be exposed to flood forces.

Debris load, the amount and type of debris carried by floodwaters, can result in significant impact forces against a structure.

Debris can also adversely affect a structure by blocking channels and interfering with natural drainage thereby increasing the magnitude of other flood parameters. Ice poses significant debris hazards, particularly during early spring floods.

Manufactured homes are especially vulnerable to damage caused by debris impact. In addition, typical foundations, such as unreinforced masonry, offer little resistance to battering from debris. An inadequately elevated and anchored manufactured home can itself become part of the debris load during a flood. Further information concerning flood parameters is shown in Appendix C.

In addition to flooding, the manufactured home installation will be subjected to wind forces, sometimes occurring concurrently with flooding, thereby placing additional loads on the manufactured home and its foundation.

WIND HAZARDS

High winds, most notably in coastal and mountainous areas, will impose forces on a manufactured home and the structural elements of its foundation. Damage potential is increased when the wind forces occur in combination with flood forces. In addition, as the manufactured home is elevated to minimize the effects of flood forces, the loads on the elevated structure itself, due to wind, are increased. Figure 2.5 shows annual extreme fastest wind speed 30 feet above ground for the 100-year mean recurrence interval.

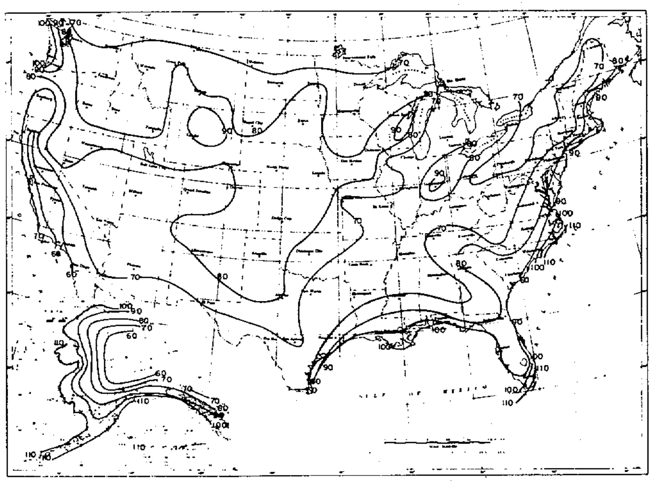


Figure 2.5 Wind Speed Map

Wind forces exert pressure on a manufactured home and its supporting foundation. Structural components, such as walls and roofs, are affected by winds and are designed to withstand certain wind forces. Figures 2.6 and 2.7 illustrate these lateral forces and their results.

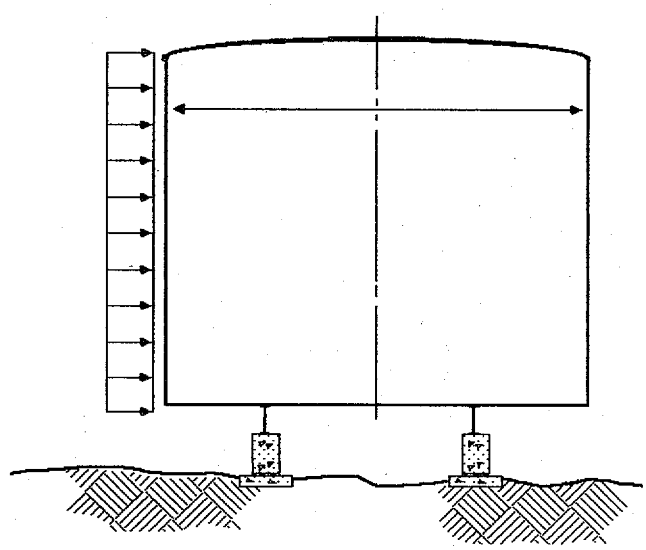


Figure 2.6 Lateral Wind Force

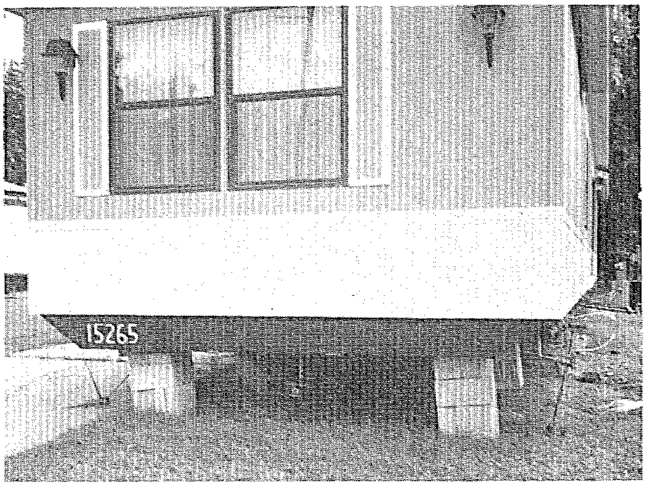


Figure 2.7 Wind Damage

Uplift affects the roof of the manufactured home and its anchorage/connection to the foundation system, as shown in Figure 2.8.

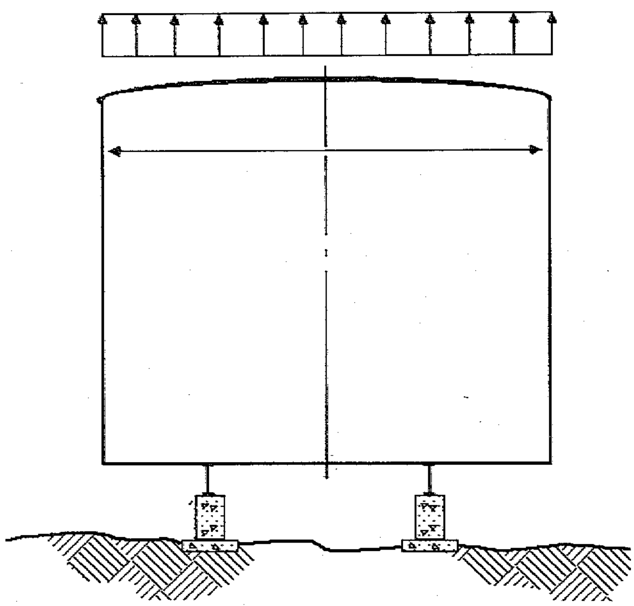


Figure 2.8 Wind Uplift Force

Wind forces also affect all connections within the manufactured home as well as those securing the manufactured home to the foundation system.

Wind is also of particular importance as it affects the loads imposed on the manufactured home itself. The Manufactured Home Construction and Safety Standards (MHCSS) currently provides for structural integrity of manufactured homes under two conditions—lateral and uplift loads imposed by wind.

In hurricane zones, the lateral and net uplift design loads are 25 pounds per square foot (psf) and 15 psf respectively; in non-hurricane zones, they are 15 psf and nine psf respectively as shown in Figure 2.9.

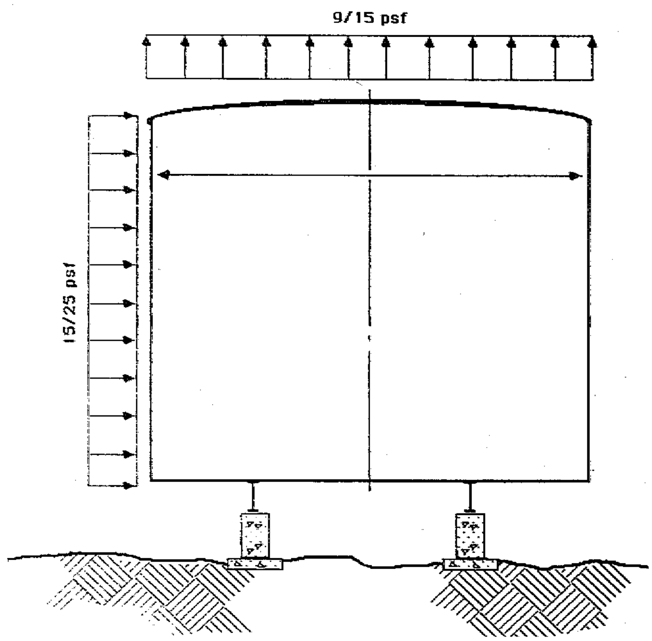


Figure 2.9 Wind Design Loads

This is important in site considerations because wind and flood forces can be additive, thereby taxing the structure, its foundation system, and any anchoring mechanisms.

If the manufactured home is located above the flood elevation, the anticipated wind loads would still be applied. However, they become increasingly more important to the foundation design as elevation of the manufactured home is increased.

When considering siting techniques and design criteria, the details on flooding and wind conditions must be determined because they will dictate what techniques can be used to reduce flood hazard damage. As previously discussed, these include depth, velocity, duration, rate-of-rise, and frequency of flooding and the anticipated forces due to wind. With this information chapters three and four can be used to develop an effective design strategy for flood loss reduction.

ELEVATION AND ANCHORING TECHNIQUES

ELEVATION AND ANCHORING TECHNIQUES

Site-specific flood information is critical when considering a siting strategy for a manufactured home or manufactured home community. In some cases, the information gathered may ultimately result in a decision against siting in the area or may indicate that no additional flood-related safeguards are necessary.

This chapter outlines general techniques which focus on elevating the manufactured home in riverine or coastal flooding areas. Chapter IV provides specific criteria and calculational procedures to address the capability of the design techniques to withstand anticipated flood and wind loads.

ELEVATION ON FILL

Earth fill, shown in Figure 3.1, is a widely used elevation technique that, with proper construction practice and materials, can be a means of elevating a manufactured home above flood levels.

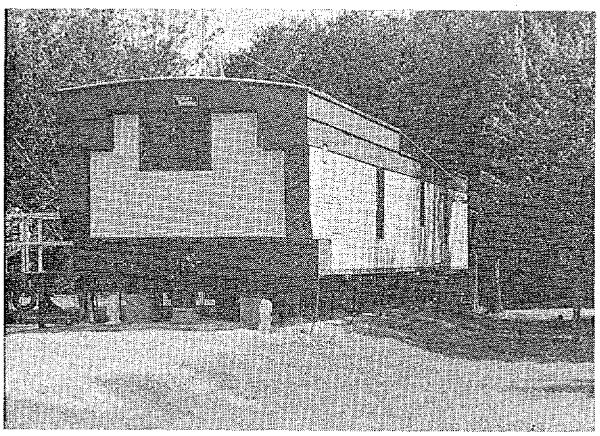


Figure 3.1 Earth Fill

Fill should not be used in areas subject to floodwaters having a velocity greater than 10 feet per second (fps) due to the risk of scour and erosion and subsequent foundation failure. In addition, fill should not be used where it will constrict the flow of floodwaters and cause increased flood elevations or velocity.

Advantages of fill include its appearance, ability to improve access to the manufactured home, ability at some sites to connect the filled area to higher ground for emergency evacuation in a flood, and protection of building elements from deterioration caused by exposure to floodwaters.

If the desired elevation is achieved by earth fill and floodwater is not anticipated under the manufactured home, a conventional installation can be implemented, as shown in Figure 3.2, in accordance with the manufacturer's instructions and state or local installation standards as discussed in Chapter I.

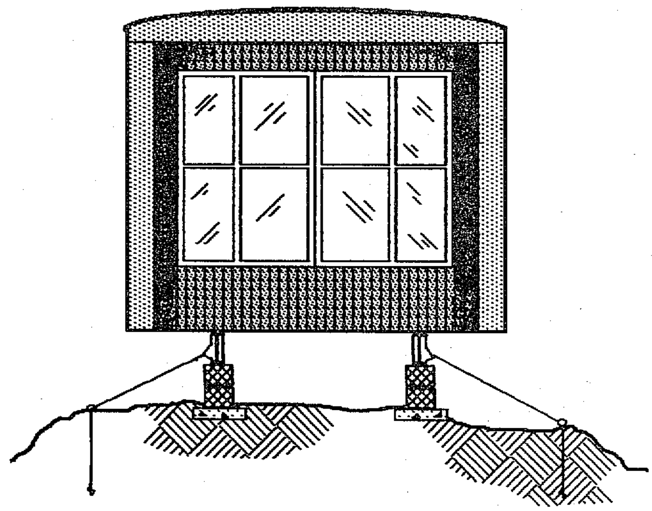


Figure 3.2 Earth Fill and Conventional Installation

If elevation by earth fill is being considered as a partial solution with floodwater anticipated over the fill, as shown in Figure 3.3, the manufactured home will have to be elevated and anchored using techniques presented later in this chapter. In this situation, the earth fill will have to be selected and placed in consideration of soil saturation and any anticipated floodwater velocity.

In the manufactured home community shown in Figure 3.4, new sites were being developed. A review of flood history showed recurrent flooding with low velocity and three to four foot depths. By elevating the new sites with two feet of earth fill, a conventional installation was used and the occupied portion of these homes is now protected during flooding.

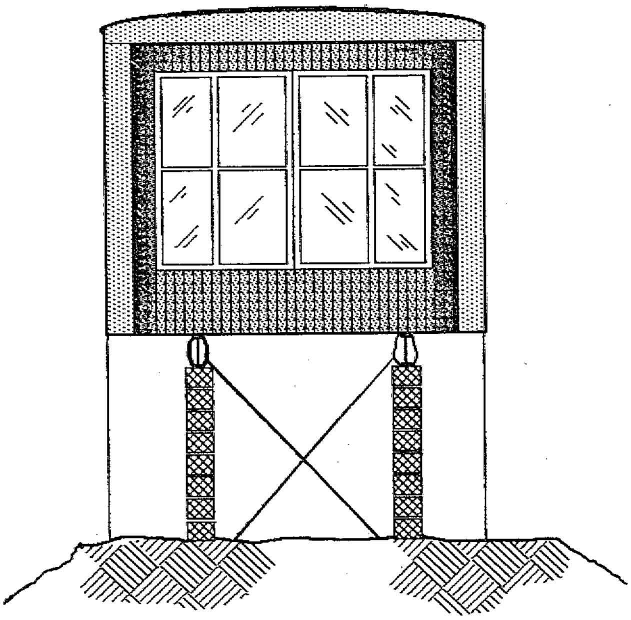


Figure 3.3 Earth Fill and Elevated Foundation

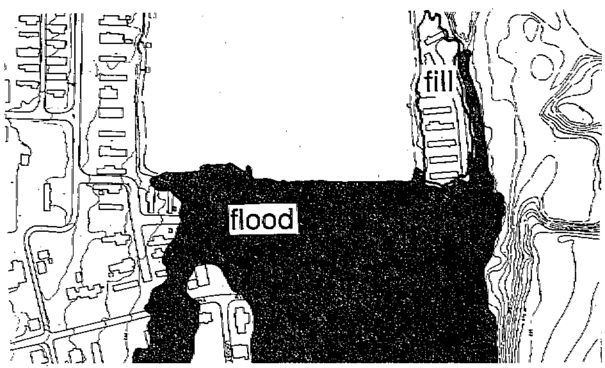


Figure 3.4 Earth Fill Site Plan

The earth fill elevation approach is widely used throughout the United States in low velocity "backwater" areas. Another example is shown in Figure 3.5.

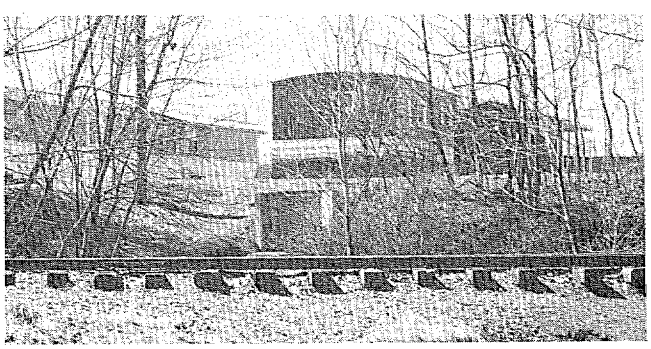


Figure 3.5 Earth Fill

Prior to filling, the area upon which earth fill is to be placed, including a five foot strip measured horizontally beyond and contiguous to the top line of the earth fill, should be cleared of standing trees and snags, stumps, brush, down timber, other vegetation, and all objects on and above the ground surface or partially buried as shown in Figure 3.6. The area should also be stripped of topsoil and debris.

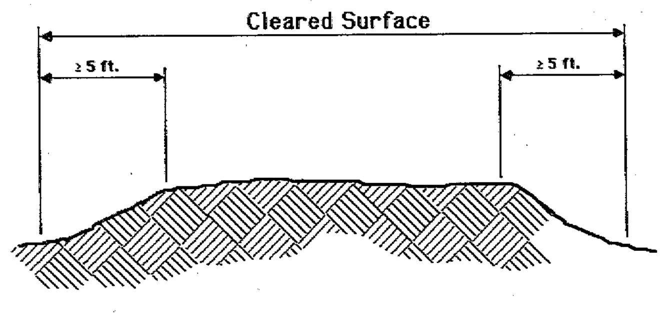


Figure 3.6 Fill Areas

Earth fill material should be of a selected type, preferably granular and free-draining. The fill should be placed in layers not exceeding 12 inches with each layer compacted with rollers or vibrating compacting equipment. Earth fill selection and placement should include consideration of the effects of saturation from floodwaters on slope stability, uniform and differential settlement, and scour potential.

The minimum distance from any point of the building perimeter to the edge of the fill slope should be either 25 feet or twice the depth of fill at that point, whichever is greater.

Slopes for granular fills should be no steeper than one and a half feet horizontal to one foot vertical unless data justifying steeper slopes are developed. For slopes exposed to flood velocities of less than five feet per second, grass, vine cover, weeds, brush, and similar vegetation undergrowth will provide adequate scour protection. For velocities up to 10 feet per second, stone or rock slope protection should be provided. Fill should not be used in areas subjected to velocities higher than 10 feet per second.

Depending upon state or local regulations, individual sewage systems (septic systems) may be prohibited in watersheds of the public water supply system. Where septic systems are allowed the use of earth fill will most likely be precluded due to its impact on the performance of the individual sewage system. This is because the additional earth fill will affect the absorption rate of the system. If earth fill is to be considered in conjunction with individual sewage systems, the local building department should be consulted.

ELEVATED FOUNDATIONS

Elevated foundations are structural techniques for elevating a manufactured home above a specified flood level. Such techniques, as shown in Figure 3.7, include piers, posts, piles, and similar structural arrangements. These elevated foundations are designed to withstand anticipated flood and wind loading and manufactured home weight while serving to reduce flood loss by raising the manufactured home above the anticipated flood level.

It is important to note that for any foundation design that elevates the manufactured home above the anticipated flood level, the manufactured home must be anchored to the foundation or ground to resist anticipated wind forces. This is discussed in the "anchoring" section of this chapter.

As discussed in Chapter 1 and shown in Figure 3.8, a conventional manufactured home installation consists of blocking on piers placed at intervals to support the steel frame of the home.

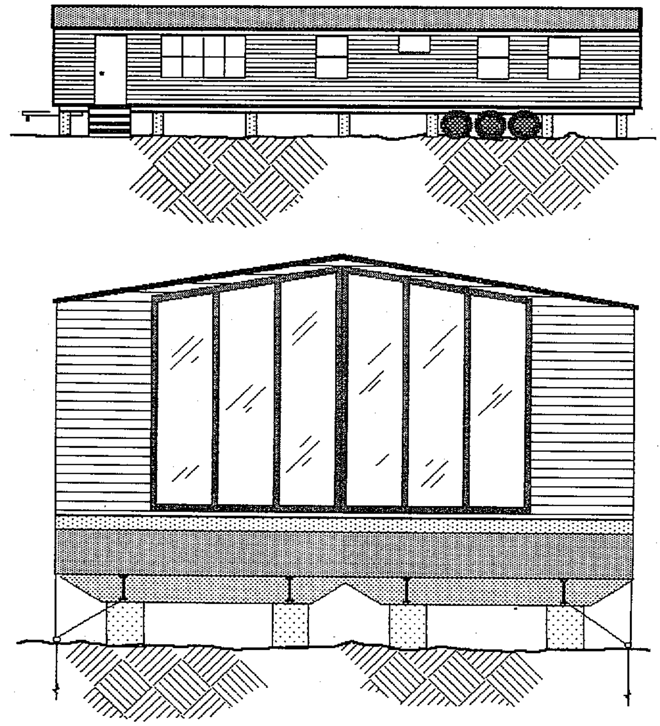


Figure 3.8 Conventional Installation Components

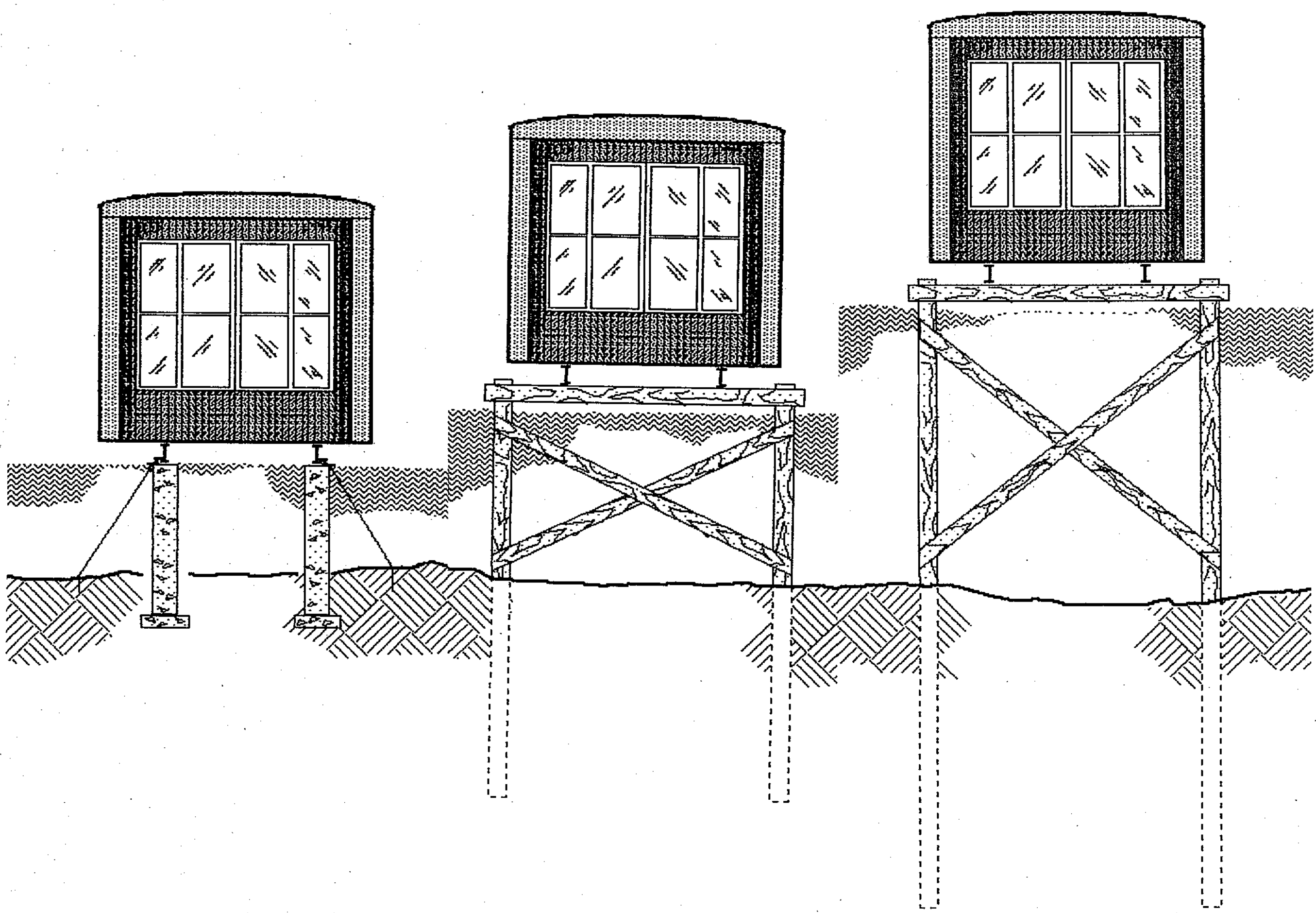


Figure 3.7 Elevated Foundations

This generally results in elevation of the manufactured home two to three feet above grade. The use of techniques to achieve additional elevation should not override the minimum requirements for steel frame support and set-up as specified in the manufactured home's installation manual and ANSI Standard A225.1-1982. In general, spacing of supporting members should not exceed 10 feet and additional intermediate supports may be required for concentrated loads or areas adjacent to large wall openings. In some cases, perimeter blocking may be required by the manufacturer and must also be provided in any elevated installation.

Piers—As shown in Figure 3.9, a pier foundation system uses brick, concrete masonry units (CMU), or cast-in-place concrete. Lateral forces are resisted through vertical steel reinforcement, bracing, and anchoring and augmented by the dead weight of the pier and footing.

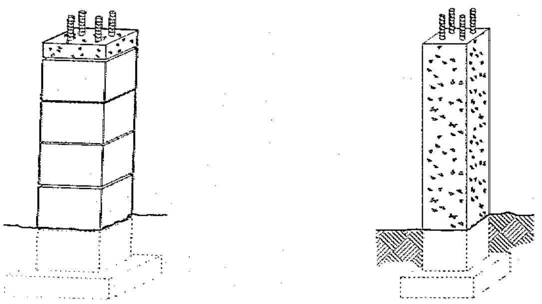


Figure 3.9 Pier Designs

Generally piers have a low resistance to lateral forces. This, in addition to the potential for scour and erosion of the footing, makes the use of piers inappropriate in areas subjected to floodwater velocity.

Built-up piers are generally effective for elevations up to 10 feet, depending on their size, reinforcement, soil conditions, and anticipated lateral forces. In general, height should be limited to a maximum of 10 times their least dimension, with square piers preferable to rectangular piers to minimize affected loads.

In all but a few cases built-up piers should be a minimum of 12 inches by 12 inches and reinforced with a minimum of four No. 5 steel bars. These minimum requirements apply whether the pier is freestanding or laterally braced. In cases where large loads are anticipated, the pier cross section should be increased or additional reinforcement such as cross bracing added. A larger cross section can be obtained by using piers two feet or more in width with the long dimension placed parallel to any anticipated flow, as shown in Figure 3.10, buried at least 30 inches below grade.

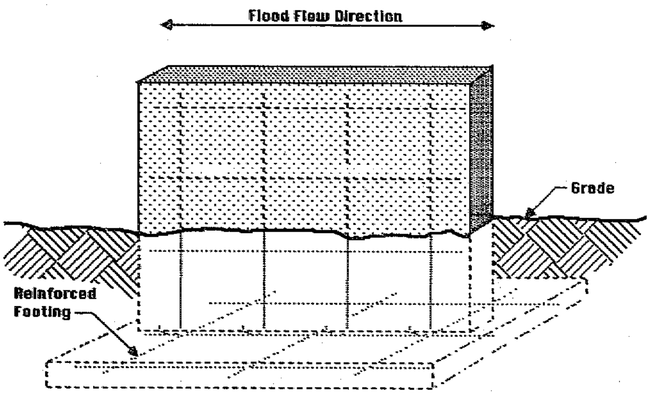


Figure 3.10 Large Pier Design

Built-up piers should be laid with type M or S mortar. Hollow concrete masonry units should be filled with concrete or high strength mortar after reinforcement as shown in Figure 3.11.

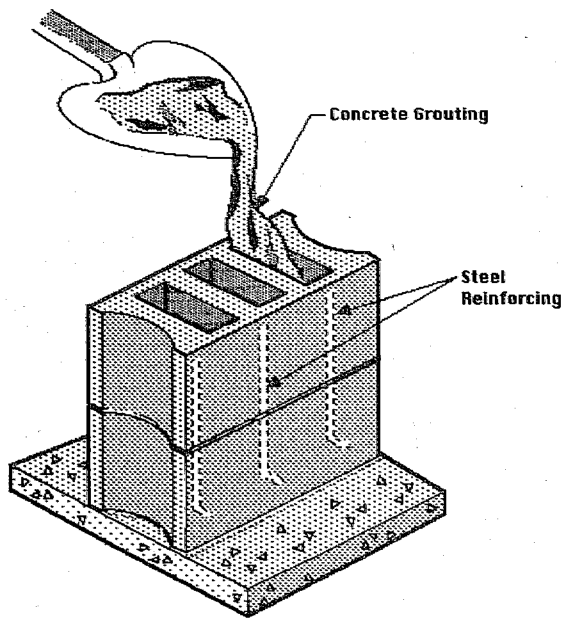


Figure 3.11 Filling of Piers

Cast-in-place concrete piers can also be used and are essentially reinforced concrete columns. They are cast in forms set in machine or hand-dug holes. The holes can be widened or belled at the base to form a footing integral with the pier, or a separate footing can be constructed as shown in Figure 3.12. In the few cases where soil bearing capacity may be adequate to support the maximum vertical load and no flood velocity is anticipated, the footing can be eliminated and loads left to end bearing and friction between soil and pier.

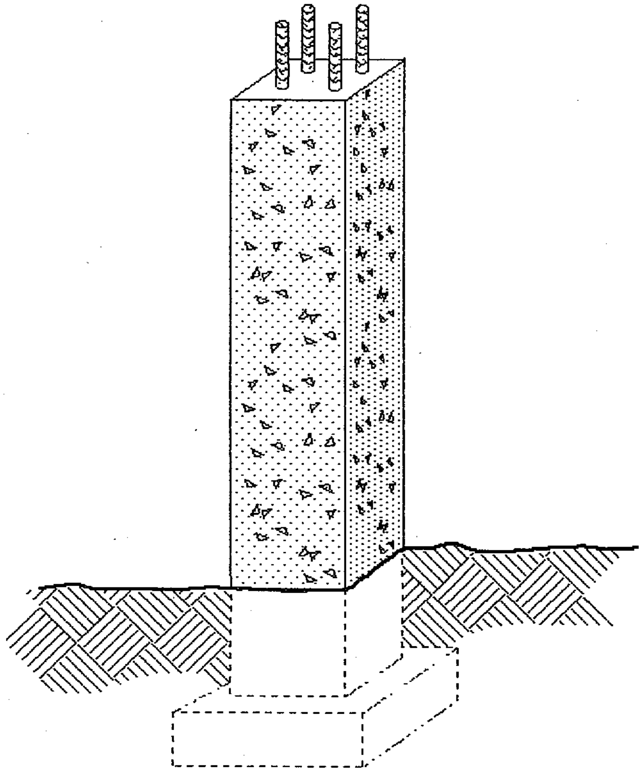


Figure 3.12 Cast-in-place Pier

The dimensions, reinforcement, and spacing of cast-in-place concrete piers depend on the manufactured home support spacing requirements as well as anticipated flood and wind loads.

Pier footing sizes are a direct function of soil bearing capacity and loading. Depth of pier footings depends on local frost penetration levels and expected flooding, wind, and erosion levels. Local codes may provide specific requirements for the size and depth of footings based on local soil conditions. At a minimum the bottom of the footing must be at least 30 inches below grade or to the frost line, whichever is greater.

As with all elevation techniques, footings in areas where the soil bearing capacity is not known can be unstable and should, therefore, be designed with the guidance of a soils engineer. Design calculations, suggested construction details, and anchoring criteria for pier foundations are presented in Chapter IV, "Design of Elevated Foundations."

Posts—Posts may be used to elevate a manufactured home above an anticipated flood level. The height of the posts, design requirements, and the need for additional anchoring will be determined by anticipated flooding conditions, wind loads, and the type of terrain and soil on the manufactured home site.

As shown in Figure 3.13, posts replace the blocking arrangement described for a conventional installation and carry the weight of the manufactured home by bearing on undisturbed soil or a concrete bearing pad.

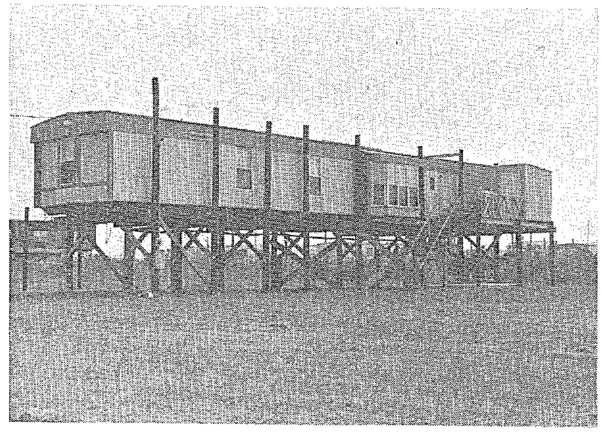


Figure 3.13 Post Foundation

Lateral forces from moving water, wind, and debris are resisted by embedment in the soil, post size, horizontal cross beams, and by the connection of the steel I-beams of the manufactured home chassis to the foundation. Posts are a suitable elevation method in areas where the soil has the bearing capacity to resist the manufactured home foundation loads and where high velocity floodwater is not anticipated. Recommended post sizes and depths of embedment for various wind and roof load zones and heights above grade are presented in Chapter IV, "Design of Elevated Foundations."

Post foundations can be of wood, concrete, or steel with members set in predug holes or connected to poured concrete piers. Posts can be round, square, or rectangular and may range from four to 12 inches in cross section. Rectangular posts are easier to frame into and are generally stronger for a given cross sectional area.

Post foundation holes may be excavated by hand or machine; however, holes deeper than six feet generally require machine assistance. The post design, method of installation, and depth to which posts should be embedded are addressed in Chapter IV and depend on many conditions including: the type of soil; the depth of the frostline; anticipated lateral loads from floodwater; debris impact; wind forces; anticipated erosion from water flow; and the size of the posts. Post holes should be a minimum of eight inches larger in diameter than the greatest dimension of the post section, thereby allowing for proper alignment and backfilling.

Based on the design loads and the allowable soil bearing capacity, the post can be set on undisturbed earth at the bottom of the hole as shown in Figure 3.14. In this case, the bearing capacity of the soil will govern the elevated foundation design as presented in Chapter IV, "Design of Elevated Foundations."

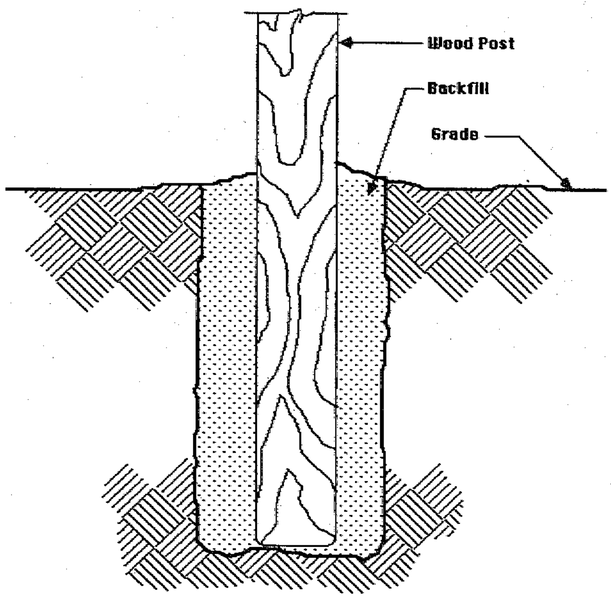


Figure 3.14 Post Set on Soil

Where additional support is needed because of inadequate soil capacity, bearing capacity can be improved by pouring a concrete bearing pad at the bottom of the hole as shown in Figure 3.15. This pad should have a diameter at least twice the post diameter and be one post diameter thick (a minimum eight inches thickness is recommended).

After proper post alignment in the hole is achieved, clean, well-compacted backfill is necessary to ensure a post configuration with good lateral stability and resistance against wind and flood loads.

Common backfill materials are sand, gravel, crushed rock, pea gravel, soil cement, concrete, and earth with granular fills that provide good drainage. Backfill materials should be dampened and mechanically tamped during construction to provide adequate compaction.

Backfilling the hole with concrete, as shown in Figure 3.16, rather than gravel or sand adds stability to the structure and increases the bearing area. Soil cement is an economical alternative to concrete and attains nearly equal strength in all soils except clay. Soil cement is made by mixing the earth removed from the hole with cement in a ratio of one part cement to five parts earth,

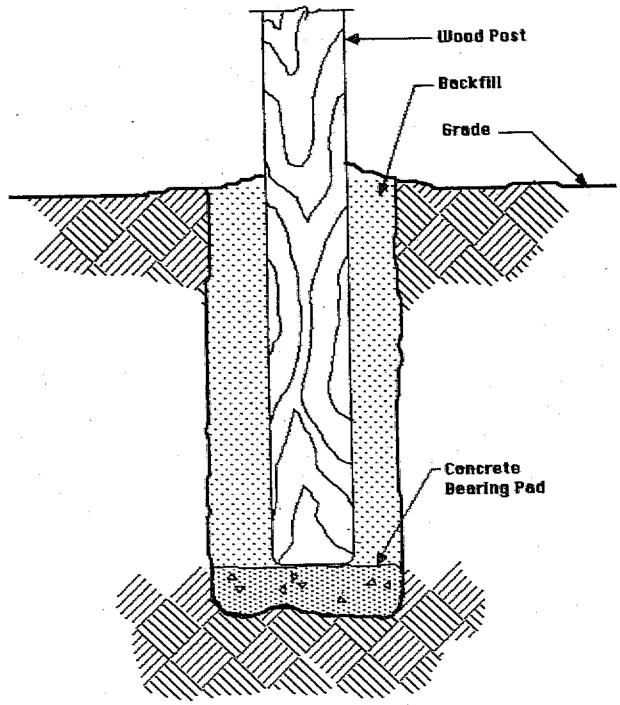


Figure 3.15 Post Set on Bearing Pad

plus water as directed by the manufacturer. To achieve the best results, all organic matter should be removed from the earth, and it should be sifted to remove all particles larger than one inch.

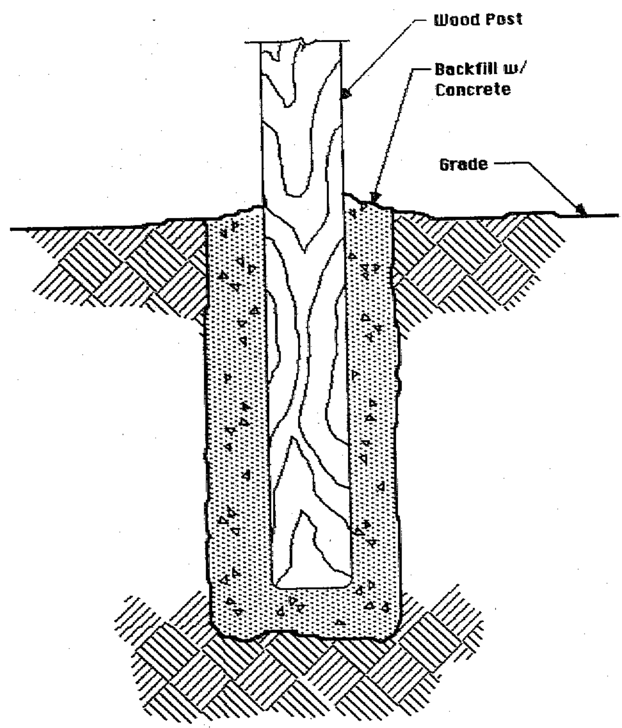


Figure 3.16 Post Backfilled with Concrete

Flood and wind forces are less likely to overturn or uplift posts if the posts are anchored to a foundation. Two ways to anchor posts are to embed them in concrete or to fasten them to metal straps, angles, plates, etc., that are themselves anchored in concrete footings, piers, or pile caps.

Figure 3.17 shows one method of anchoring wood posts in concrete. Spikes or lag bolts 5/8 to 3/4 inch in diamenter are driven into the post around its base. The post is placed into the hole, secured to bracing restraints to prevent movement and the concrete is poured.

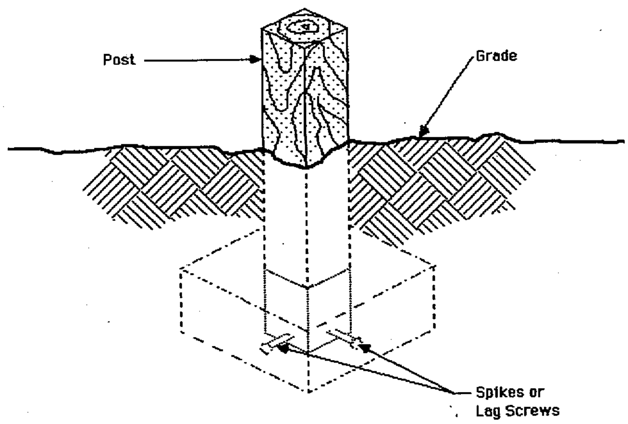


Figure 3.17 Post Anchoring

Above-grade wood posts supported by concrete piers may also be considered as shown in Figure 3.18. In this case, the entire length of the post is accessible for maintenance; however, the connection between post and pier must be designed to resist all applied loads.

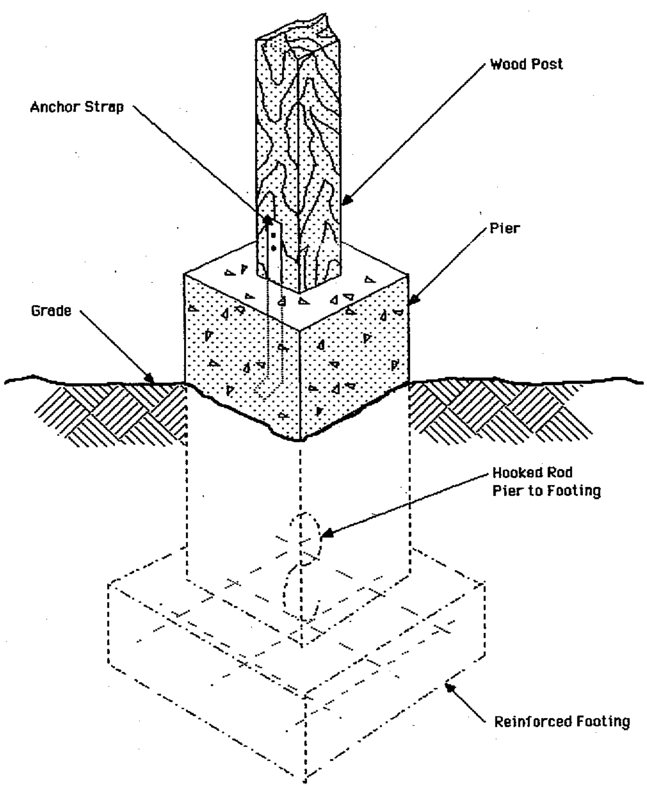


Figure 3.18 Post Anchoring

A calculational procedure, design guidelines, and examples for determining the adequacy of a particular post system design for elevating manufactured homes under differing loads is presented in Chapter IV.

Piles—Piles, as shown in Figure 3.19, are vertical supports made of wood, steel, or reinforced concrete which can be driven into the ground to support a manufactured home. The use of properly driven and embedded piles is an elevation technique that is appropriate in flood-prone areas subject to high water velocity and depth and having poorly drained soils with low bearing capacity, such as coastal areas.

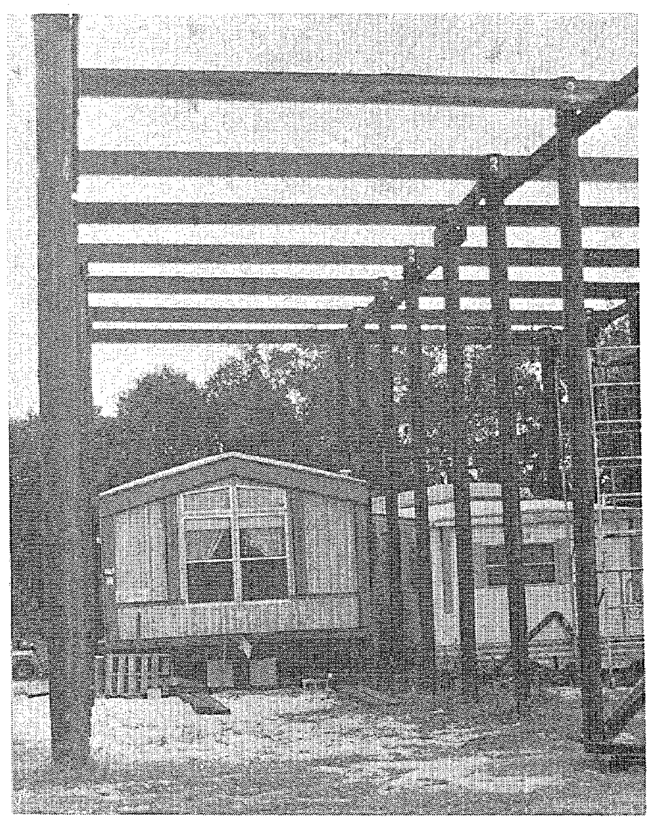


Figure 3.19 Piles

Round timber piles, which are frequently used, are generally available in longer lengths than square timbers; and for lengths greater than 25 feet, round piles are frequently the only piles available. A minimum tip diameter of eight inches and a butt or top diameter (at the floor beam level) of 11 inches or more are recommended for round piles.

There are several methods available for embedding piles. Pile driving is an excellent method due to the strength of the pile and earth interface to resist vertical and horizontal loads. An alternative, the drop hammer, consists of a heavy weight that is raised by a cable attached to a power-driven winch. The weight is then dropped five to 15 feet onto the end of the pile. Drop hammers, however, must be used with care because they can damage wood piles.

A much less desirable but frequently used method of inserting piles into sandy soil is "jetting." Jetting involves passing a high pressure stream of water through a pipe advanced alongside the pile. The water blows a hole in the sand into which the pile is continuously pushed or dropped until the required depth is reached. Sand is then tamped into the cavity around the pile and the end of the pile pounded with a sledge hammer or other available weight. Unfortunately, jetting loosens the soil around the pile. Decreased friction due to loose soil results in a lower load capacity. To increase the load capacity, jetted piles must be inserted deeper into the ground than driven piles.

If the soil content has sufficient clay or silt (has a higher shear strength), a hole can be excavated by an auger or other means and will stay open in order to drop in a pile. Sand or pea gravel is then poured and tamped into the cavity around the pile. This technique does not provide as much load resistance as driving the pile into the ground, and longer piles are necessary. Some final driving with a sledge hammer can be helpful.

As with post foundations, piles are often partly backfilled with concrete to improve their resistance to lateral loads. As shown in Figure 3.20, the area at grade around each pile can be replaced by a concrete collar extending several feet below grade.

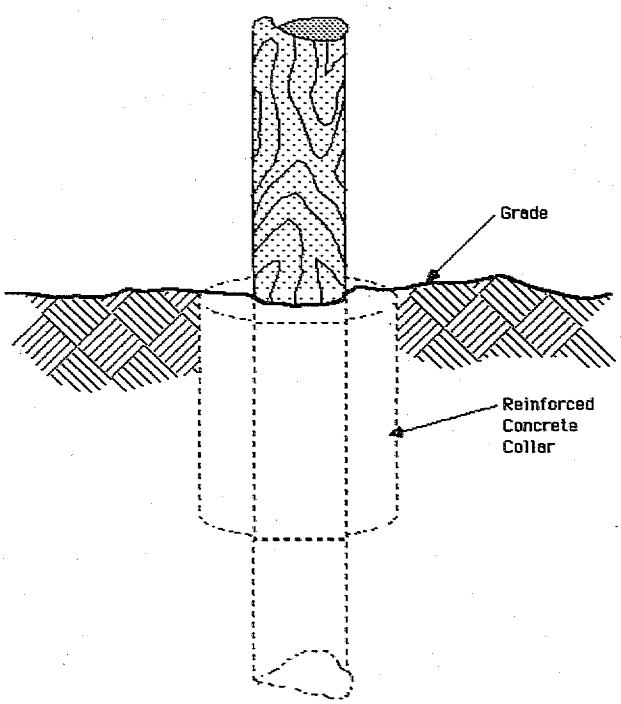


Figure 3.20 Pile with Concrete Collar

Such collars provide protection from minor erosion, add more deadweight to the structure, and increase the pull-out resistance of the pile.

The necessary pile size and depth of pile embedment depends on the number of piles used, size and weight of the manufactured home, wind and flood loads, soil bearing capacity, and potential for scour and erosion. Calculations and suggested construction criteria are presented for piles in Chapter IV.

Horizontal Beams—In a post or pile elevated foundation system, horizontal beams must be provided to support the manufactured home. As shown in Figure 3.21, these horizontal members tie opposing posts or piles together and distribute any flood, wind, or roof live loads to those vertical members and into the ground.

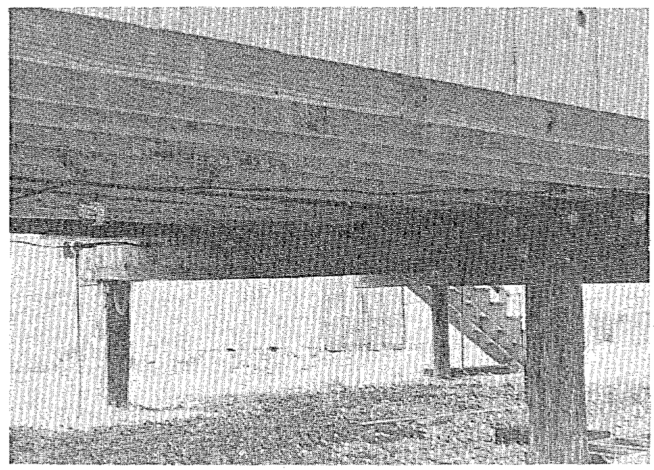


Figure 3.21 Horizontal Members

Although steel channel sections could be used for this foundation component, sawn timber beams are considered preferable based on their availability. Chapter IV presents details on the required number and size of these horizontal beams to carry various imposed loads.

Bracing Elevated Foundations—The vertical and horizontal members of an elevated foundation must be braced, as shown in Figure 3.22, to resist flood and wind induced loads. Even in areas where low loading is anticipated, bracing will provide added assurance that the elevated foundation will withstand the impact of floating debris or excessive flood or wind forces.

Although bracing placed underneath a manufactured home may be struck by floating debris or subject to other flood forces, the negative effects of these on a structure's survivability are generally outweighed by the beneficial effects of the bracing.

Knee bracing, shown in Figure 3.23, is effective in increasing lateral strength of posts or piles to resist all loads.

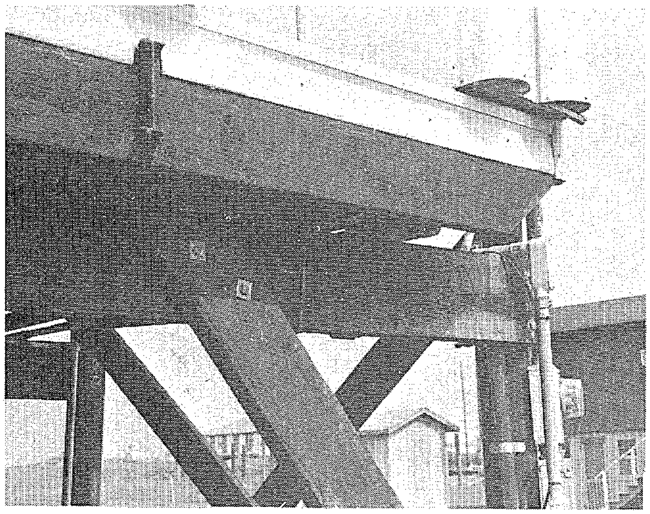


Figure 3.22 Bracing

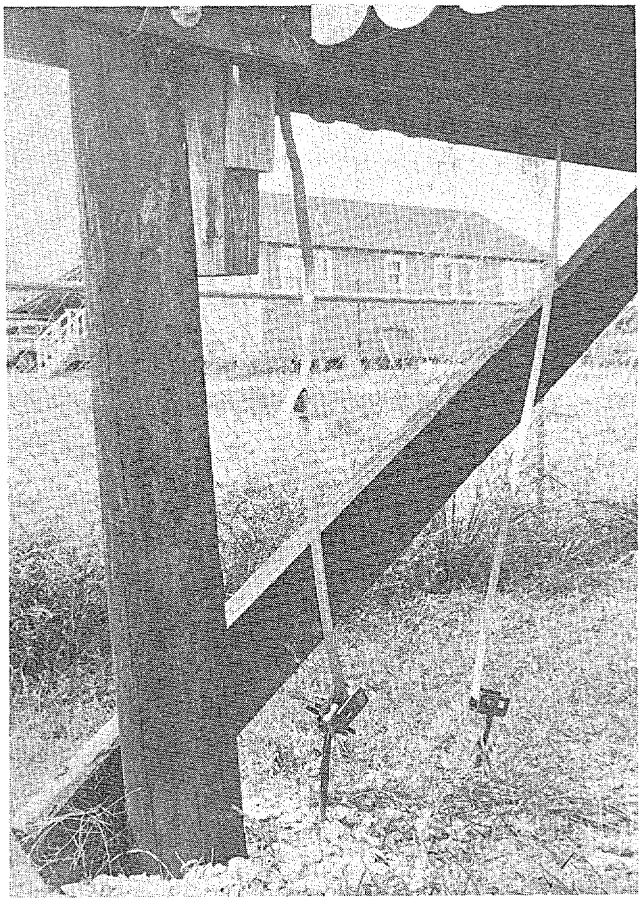


Figure 3.23 Knee Bracing

Lumber no less than two inches nominal thickness should be used with bolted connections because of the resistance to pullout forces by the bolted connection. Knee bracing should be bolted to and run between the horizontal beam supporting the manufactured home and to the post or pile.

Diagonal bracing, as shown in Figure 3.24, is bolted at the base of one post or pile and fastened in a like manner to the adjacent post or pile just below the manufactured home. Although diagonal bracing is more likely to be struck by floating debris than knee bracing, this is generally outweighed by the greater lateral stability diagonal bracing provides, especially in higher elevated manufactured homes.

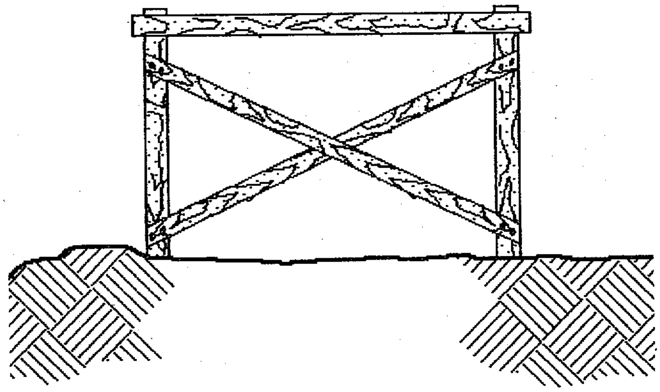


Figure 3.24 Diagonal Bracing

Steel rods, as shown in Figure 3.25, can sometimes be used to diagonally brace wood posts or piles. The rods are fitted through drilled holes filled with wood preservative and fastened with nuts and cast beveled washers. Welded connections or drill holes can be used to provide rod bracing in steel post or pile foundations.

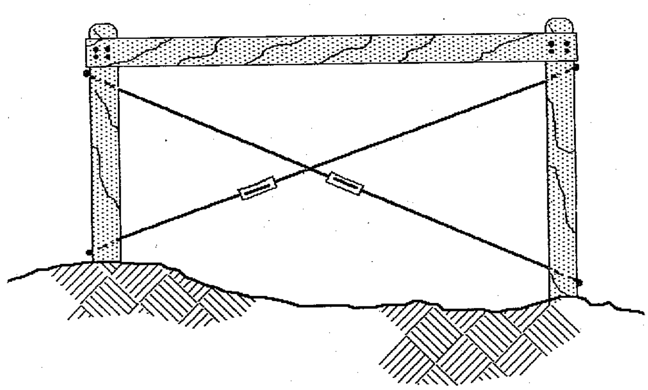


Figure 3.25 Diagonal Bracing with Steel Rods

The severe flood and wind forces encountered in coastal zones may require the use of additional special bracing techniques which should be designed in conjunction with qualified engineering consultants.

Perimeter Enclosure (Skirting)—The perimeter enclosure is a weather-resistant material which encloses the area from the bottom of the manufactured home to grade. It is primarily used to improve the appearance of the manufactured home.

Because floodwaters reach the perimeter enclosure before the floor level of the home, the design must take into account anticipated flood forces. Commonly used enclosures are not designed to resist flood or wind forces. The enclosure, as shown in Figure 3.26, may be subjected to either of these forces in addition to impact from floating debris and *must not* transfer these loads to the elevated foundation or the manufactured home. Consequently, the design must ensure that the enclosure disconnects during flooding and does not transfer any forces to the manufactured home or its foundation.

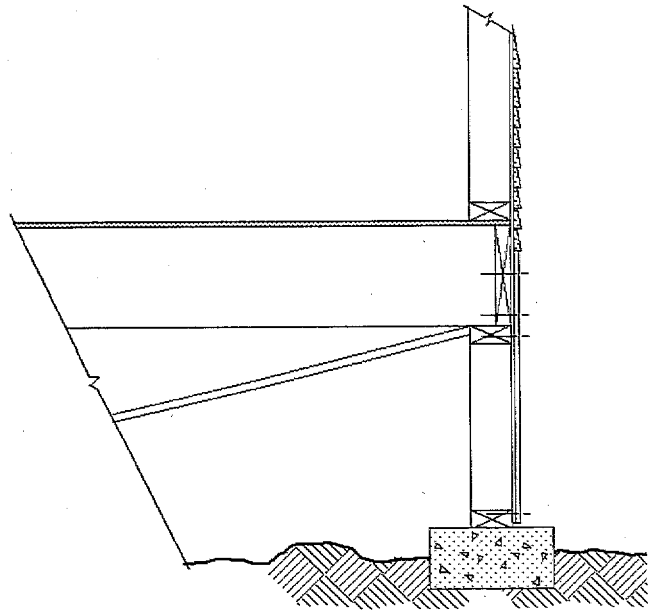


Figure 3.26 Perimeter Enclosure

Perimeter Walls —In areas with floodwater velocity less than five feet per second (fps) and where soil bearing capacity is adequate to support imposed loads, perimeter walls, as shown in Figure 3.27, can be feasible.

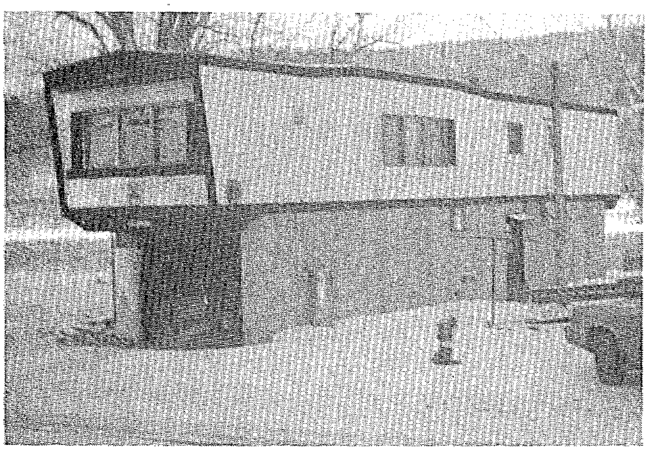


Figure 3.27 Perimeter Walls

A perimeter wall is essentially an extended foundation wall which acts as a deep beam in resisting forces in the plane of the wall. From a structural standpoint, the most important consideration is the ability of the wall to resist lateral forces. For this reason, the perimeter walls *must* provide a means of allowing floodwaters to enter the enclosure, thereby eliminating lateral loads. To minimize drag forces, the walls should be parallel to anticipated flood flow.

Supports for the manufactured home would be horizontal beams, as previously discussed, located across the span between the walls. As an option, steel I-beams could be used. Note that the manufacturer's recommended chassis I-beam support spacings must not be exceeded and, where required, perimeter blocking between the manufactured home and perimeter wall must be provided.

ANCHORING

Conventional Tie-Down or Anchoring Systems—Conventional tie-down or anchoring systems are designed to resist the lateral and uplift forces resulting from wind. The system is made up of two distinct components, tie-downs (ties) and anchors. There are two types of ties: (1) the over-the-top tie as shown in Figure 3.28, and (2) the frame tie as shown in Figure 3.29.

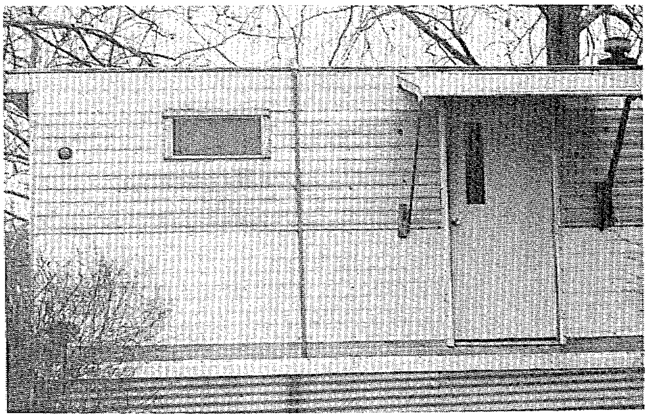


Figure 3.28 Over-the-Top Tie

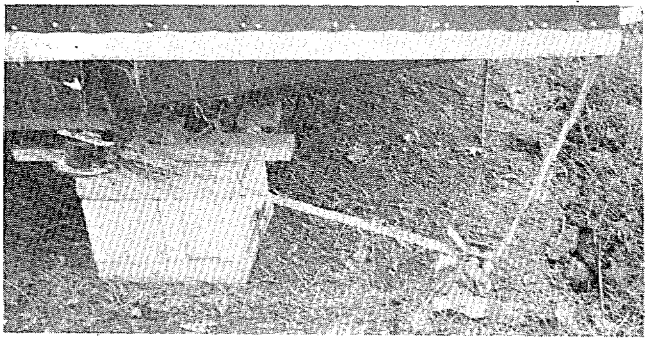


Figure 3.29 Frame Tie

The first resists vertical loads; the second resists vertical and lateral loads. Frame ties will always be required to resist lateral and uplift forces. If the manufactured home is designed for over-the-top ties they can be used in conjunction with frame ties.

Ties are made of rust-resistant steel cable or straps which fasten the home to anchors embedded in the ground. In combination over-the-top and frame ties, the cable or strap is secured to the ground anchor with a yoke-type fastener and a tensioning device, or with clamps and turnbuckles as shown in Figure 3.30.

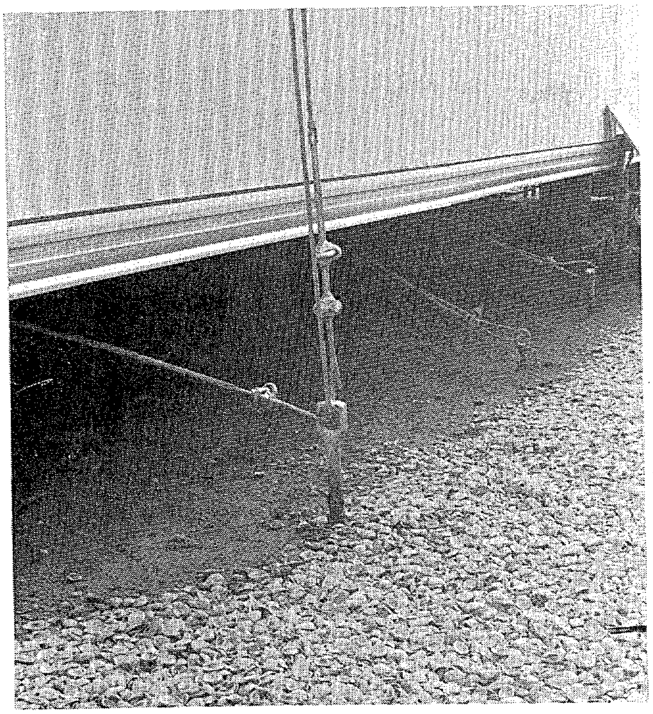


Figure 3.30 Tie Components

In frame ties, the strap is secured to the ground anchor and manufactured home I-beam as shown in Figure 3.31.

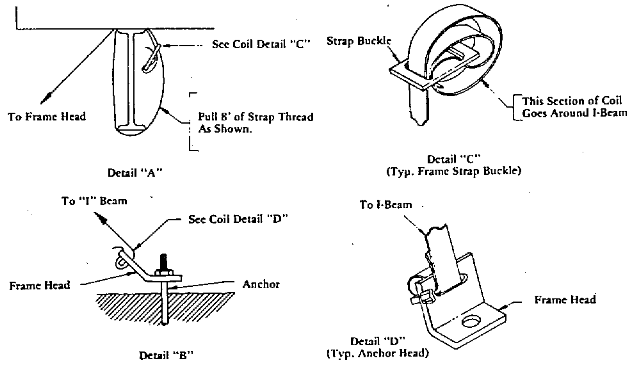


Figure 3.31 Tie Components

As indicated previously, ties are just one component of a two component anchoring system. Anchors are the component set in the ground to which ties are connected. This effectively transfers wind loads, both lateral and uplift, to the ground. As shown in Figure 3.32, these loads can be significant enough to dislodge anchors.

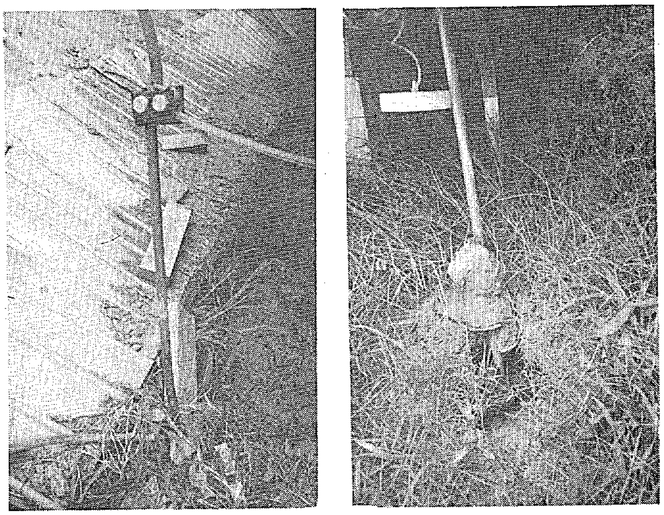


Figure 3.32 Failed Anchors

There are several types of ground anchors which can be used, including screw augers, expanding anchors, slab anchors, and concrete deadmen as shown in Figures 3.33 to 3.35.

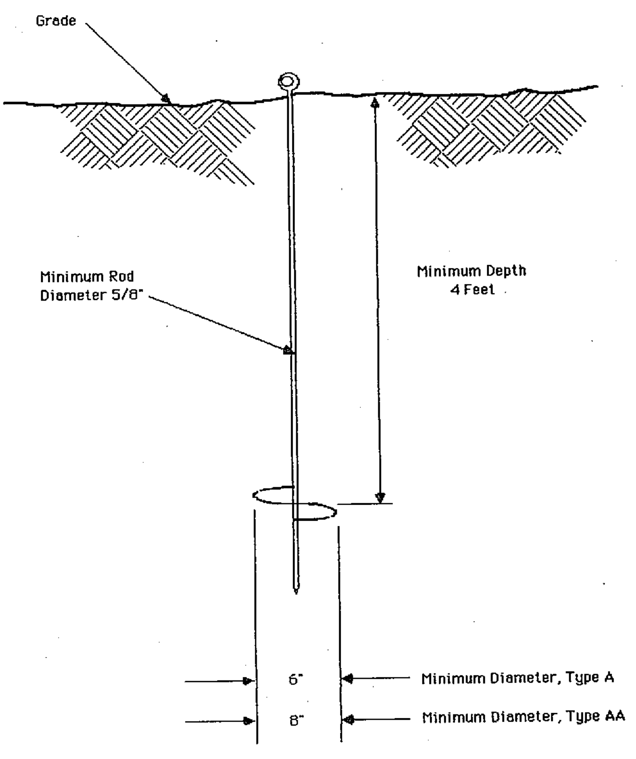


Figure 3.33 Screw Auger

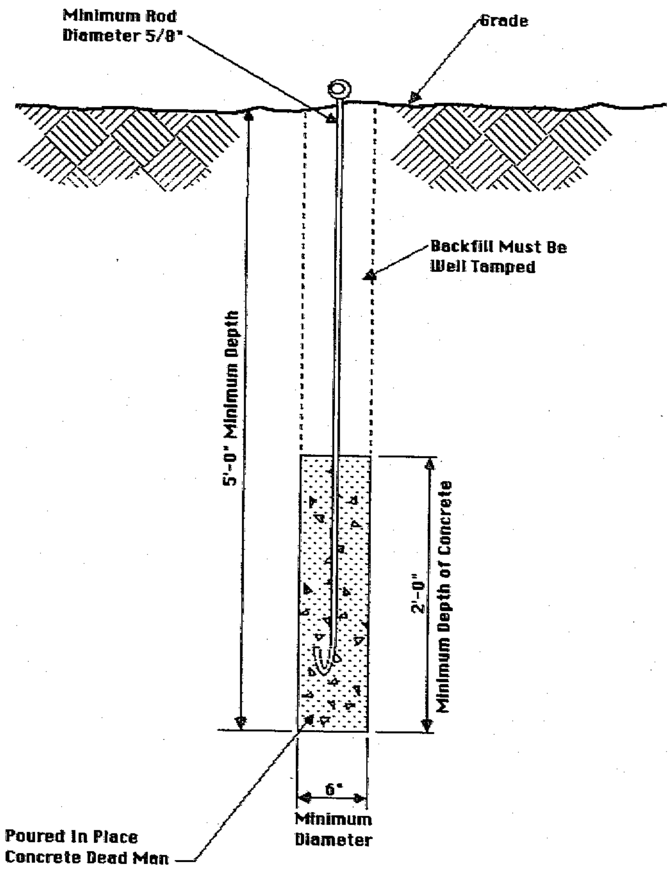


Figure 3.34 Concrete Deadman Anchor

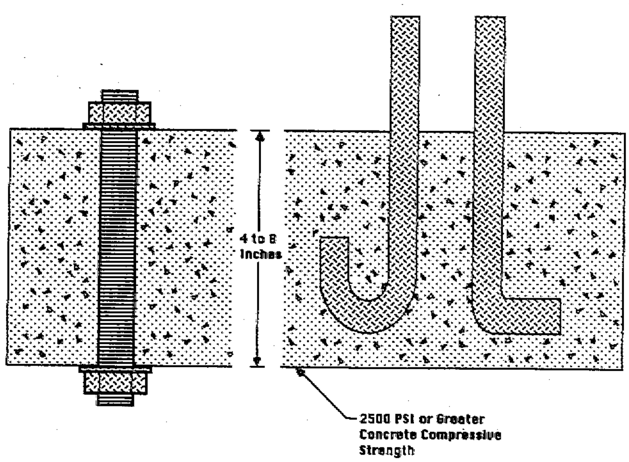


Figure 3.35 Anchors in Concrete Slab

Because different soils provide different holding strengths, the same type of anchor may not perform uniformly in all situations. For example, a six inch diameter screw auger, which might withstand a pull of 5,000 pounds in stiff clay, may withstand only 2,500 pounds in sandy clay.

The holding power of ground anchors can be determined by conducting pullout tests or by consulting with an anchor manufacturer who should be able to provide data on anchor capacity for the various kinds of soils anticipated. If soil conditions are such that the required degree of holding power is not attainable, or if the anchor selected cannot withstand anticipated loads, use of larger sized anchors or additional anchors and ties will be necessary.

Anchoring and Elevated Foundations—The necessity of elevating the manufactured home above the expected levels of flooding is critical. As previously discussed, elevating the manufactured home can be accomplished using a variety of techniques such as fill, piers, posts, or piles. Once elevated above the expected flood level, it is necessary that the manufactured home be anchored to resist wind forces. Depending on the type of elevated foundations used, the manufactured home can either be anchored to the ground using devices such as ground anchors or anchored directly to the elevated foundation.

Pier foundations can have limited resistance to lateral loads. It is, therefore, important to minimize the transfer of lateral wind loads to this type of foundation. Devices independent of the foundations, such as ground anchors, must be used as shown in Figure 3.36.

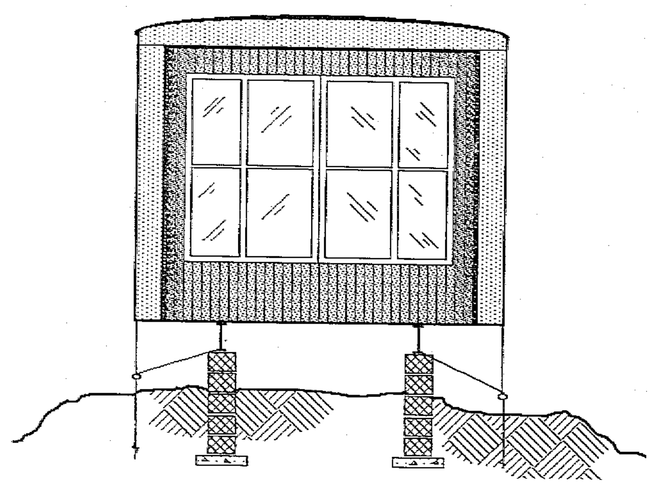


Figure 3.36 Anchoring on Pier Foundation

A post or pile foundation has much greater resistance to lateral loads, and all lateral loads can be transferred directly to the foundation. The manufactured home can be anchored directly to the foundation using two basic methods. If a manufactured home is designed for over-the-top ties and frame ties, the ties can be connected directly to the elevated foundation as shown in Figure 3.37.

If the manufactured home is designed for frame ties only, the I-beams can be connected directly to the horizontal beam as shown in Figure 3.38.

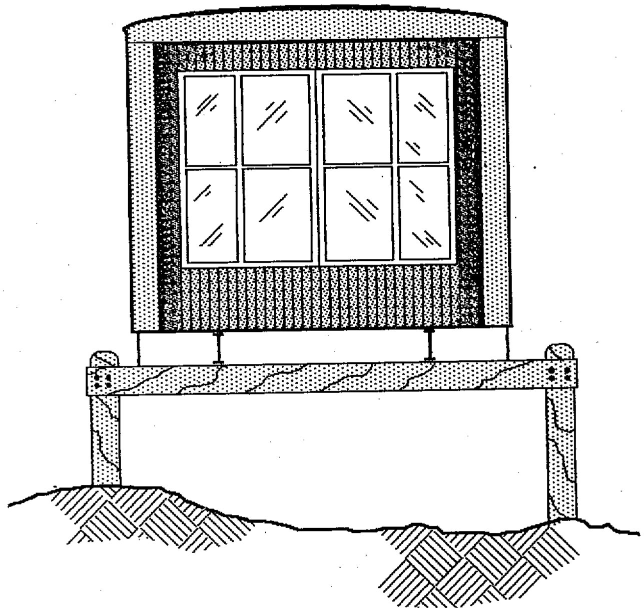


Figure 3.37 Anchoring on Post or Pile Foundation

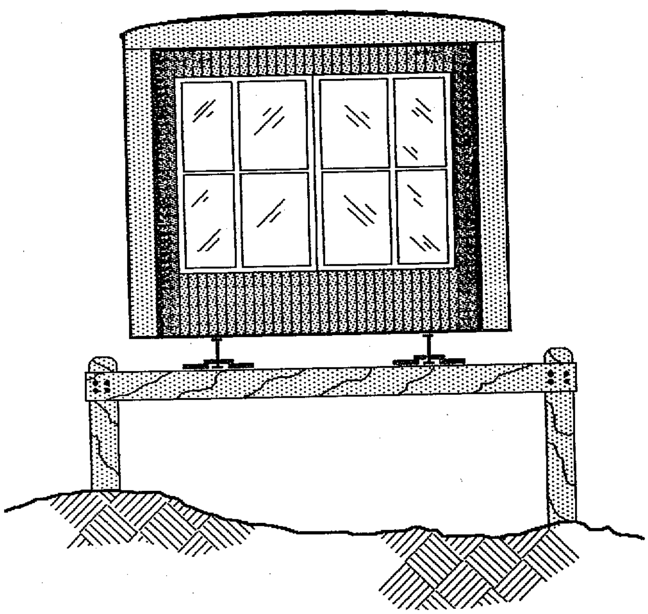


Figure 3.38 Frame Ties

In all cases the intent of anchoring is to ensure the manufactured home does not become dislodged from the elevated foundation due to the impact of wind forces.

The type and number of manufactured home anchoring connections for elevated post and pile foundations is presented in Chapter IV.

EVACUATION

The temporary relocation of manufactured homes from a flood-prone site prior to flooding has been practiced successfully in some areas, as shown in Figure 3.39. Such action may be a viable strategy for manufactured home parks or subdivisions that were established prior to the availability of flood elevation data, where manufactured homes are below the base flood elevation.

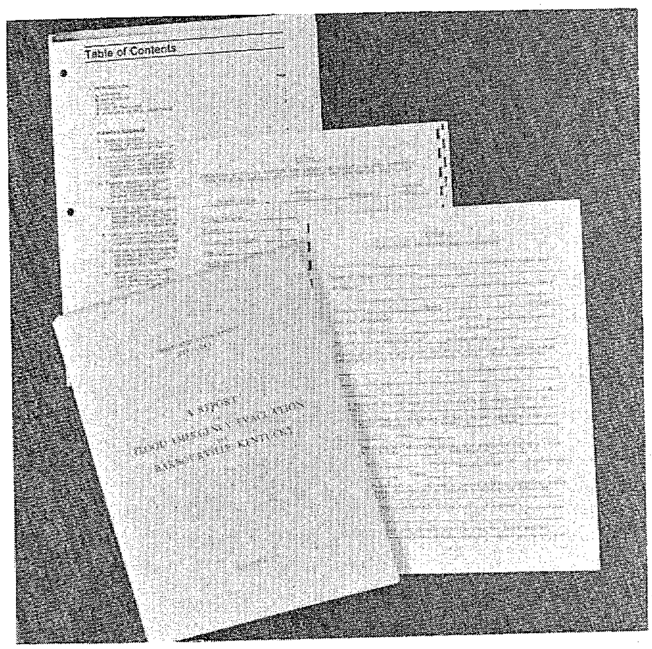


Figure 3.39 State and Local Evacuation Plan

However, it must be recognized that this procedure is heavily dependent on the mobility of the manufactured home and requires an extremely comprehensive evacuation strategy. In addition, flood insurance coverage under the NFIP may not be available for manufactured homes which have either not been elevated or properly anchored in accordance with the community's adopted ordinances for participation in the NFIP.

It is important that a plan to relocate manufactured homes during a flood event be coordinated with and involve local emergency management authorities. It is crucial that an evacuation strategy be pre-planned, that is, the procedures must be developed and in place prior to a flood being imminent. Also, such a plan is ideally executed as a group effort rather than as an individual endeavor so that "logjams" and civil disorders can be avoided or minimized.

A primary and major consideration in developing an evacuation plan is the availability and capacity of evacuation routes and temporary storage areas. It is absolutely critical that the movement of manufactured homes will in no way interfere with any concurrent evacuation of inhabitants of an area threatened by flooding. This is especially important in areas with limited escape routes or areas where mass evacuations may be necessary, such as hurricane zones. Adequately protected sites must be available at which the manufactured homes can be temporarily stored until it is determined that they can be returned to their permanent sites.

Another important element of an evacuation plan is the need for an effective early-warning system. Considerable time is required for the actual implementation of an evacuation, therefore adequate warning is essential. Lead time required will vary by situation and is composed of several factors, some tangible and some unpredictable.

Once the decision is made to evacuate, the plan must be initiated. As with any emergency situation, communication problems may be encountered. Participants, including owners of the manufactured homes, must be alerted. The status of evacuation routes and temporary storage areas must be assessed. Towing devices, such as trucks, tractors, crawlers, etc., must be obtained and brought to the flood zones. The manufactured homes will require preparation for transport. Utilities must be disconnected, contents must be secured, and separation from any foundation system and wind anchors must be accomplished. Coupling to the towing device is also involved. Time required for actual transport will vary depending upon distance to temporary site, number and condition of towing units, weather and traffic conditions, etc.

In addition to the time required to perform these necessary tasks, additional time will likely be required to resolve problems such as mechanical failure or lack of necessary personnel and equipment. Sufficient warning time to be provided by a warning system is a function of all of the above considerations and the number of manufactured homes to be evacuated.

The feasibility of an evacuation strategy is also affected by the availability of necessary equipment and personnel. Towing units must be procurable, and special equipment and tools will be necessary to prepare the manufactured home for transport. Jacks will be required for separation from foundation, hand tools will be necessary for utility disconnection and preparation work, and special equipment, such as portable lights and air compressors to inflate tires, should be considered. Ample, capable personnel must be available to coordinate efforts and execute the actual procedures. This includes coordination, equipment operation, manufactured home preparation, and troubleshooting.

Owners may be incapable of performing evacuation tasks themselves as certain skills may be required, particularly where safety considerations are involved, such as the disconnection of gas and electricity services. Representatives of utility services should, at a minimum, be involved in the planning process of the evacuation.

The success of the evacuation is also directly related to the condition of the manufactured homes themselves. Structural integrity must be such that the unit can be transported without damage. The manufactured home's transport system, including the chassis, axles, wheels, tires, and hitch must be well maintained. The system must either be in place and operational or capable of being readily assembled. The manufactured home must be easily separable from any foundation, skirting, wind anchors, and structural elements such as porches and additions. Quick and safe utility disconnect is also a requirement.

The actual evacuation plan must be developed based on the number of manufactured homes to be transported. Other factors must also be quantitatively assessed: evacuation routes and storage areas, towing units and available equipment and personnel. The status of these parameters, in addition to the warning system, must also be addressed. The plan should be functional, simple, and easily managed. A priority basis should be established—those manufactured homes most exposed to potential flood damage should be removed first.

Participants must be familiar with overall procedures and individual tasks. To make the plan complete, consideration must also be given to returning the manufactured homes back to their permanent sites when it is deemed to be safe. This could involve considerable restoration work.

Before development of an evacuation plan is undertaken, it should be determined that no other alternatives are practicable. The absolute conclusion that must be made is that evacuation can be accomplished safely without jeopardizing life or property.

CHAPTER IV

DESIGN OF ELEVATED FOUNDATIONS

This chapter provides information with which elevation techniques discussed in Chapter III can be evaluated to determine their ability to resist anticipated loads. In addition, the chapter presents an overview of flood-induced loads, tables of calculated forces, governing design equations, and specific technical information which can be used to determine an appropriate elevated foundation design for a manufactured home.

The capability to withstand flood-induced loads depends upon not only the site design and structural capacity of the foundation, but also upon the manufactured home itself. Therefore, it is critical to assure that the design criteria under which the manufactured home was constructed are not exceeded through the transferal of flood-induced loads to the manufactured home itself.

The minimum design criteria for manufactured homes required by the HUD's Manufactured Home Construction Safety Standards (MHCSS) are as follows:

Roof live load	40, 30 or 20 pounds per square foot (psf) depending upon anticipated location
Roof wind net uplift	15 or 9 psf depending upon anticipated location
Wall wind load	25 or 15 psf depending upon anticipated location
Floor live load	40 psf
Dead Load	20 psf

The maps shown in Figures 4.1 and 4.2 geographically depict the roof live load and wind load zones.

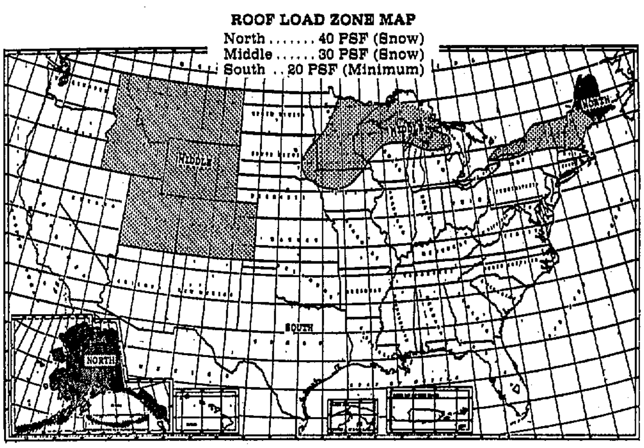


Figure 4.1 Roof Live Load

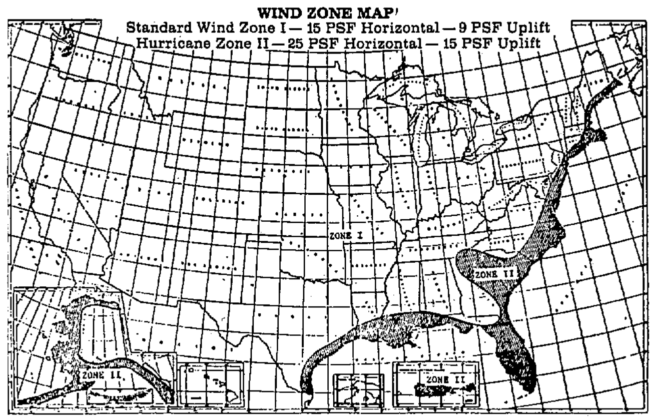


Figure 4.2 Wind Load

Generally, manufactured homes have the ability to resist only a very limited range of flood forces before the design capacity of the manufactured home is exceeded and significant damage results. For example a nine to 12 inch floodwater differential between the inside and outside of an anchored manufactured home can cause an upward floor deflection, failure of the floor decking, and floodwater inundation.

The technical information in this chapter includes consideration of the design capacity of the manufactured home. Any foundation "over design" would not improve the strength capabilities of the manufactured home design. The foundation system recommendations, therefore, are compatible with the manufactured home design criteria.

Each manufactured home siting situation will be unique. The amount of information necessary to provide specific technical guidance for all possible siting and flood loading situations would be overwhelming. This chapter, therefore, provides general guidance and technical information which can be effectively used in determining the limits of a particular candidate design. In this chapter, example calculations are provided to assist in the use of various design charts and tables. The user is cautioned, however, that the examples provided apply only to the specific conditions stated for each design problem. Extrapolations from solutions provided for specific examples are not recommended. **As previously discussed, state regulations, such as those shown in Figure 4.3, may require design by a professional engineer.**

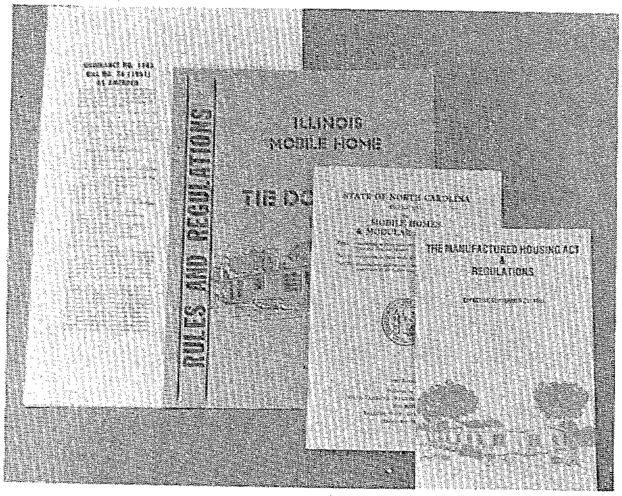


Figure 4.3 State and Local Regulations

A. FLOOD FORCES AND THEIR APPLICATION

A manufactured home installation can be affected by flood and wind-induced forces acting directly on the manufactured home, and on its elevated foundation system. This portion of the manual introduces and applies various flood and design forces to form the basis for the general design guidance for elevated foundation techniques presented in Section B of this Chapter.

Hydrostatic Forces

Hydrostatic forces are those caused by both free and confined water occurring above or below grade. These forces are equal to the product of the water pressure and the area of the surface on which they act. In addition, hydrostatic forces are equal in all directions and act perpendicular to any surface with which floodwaters come in contact.

In the case of manufactured homes, hydrostatic forces include lateral forces (those acting in a horizontal direction), uplift or buoyancy forces (those acting vertically upward), or a combination of both as shown in Figure 4.4.

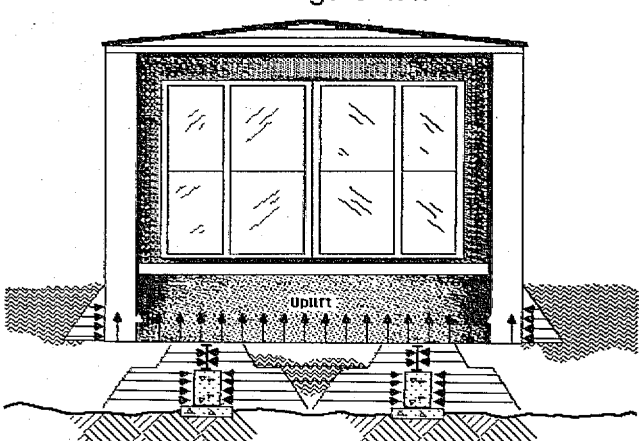


Figure 4.4 Horizontal and Vertical Forces

Lateral Forces

The lateral force of water acting against the wall of a manufactured home is related to the water's depth and specific weight.

During a flooding condition, water against a manufactured home creates a hydrostatic pressure distribution as follows:

$$p = w \times h$$

Where:

p = pressure in pounds per square foot
w = specific weight of water—62.4 pounds per cubic foot
h = distance in feet measured vertically downward from the water surface to the point of action

The resultant lateral hydrostatic force acting per linear foot on the submerged portion of the manufactured home is the total area of the pressure distribution given by:

$$F_\ell = \tfrac{1}{2}\, p \times h = \tfrac{1}{2}\, w \times h^2$$

Where:

F_ℓ = lateral force in pounds per linear foot
h = distance in feet from water surface to bottom of manufactured home chassis I-beams

A triangular distribution based on the amount of submerged area of the manufactured home results, as shown in Figure 4.5. The lateral hydrostatic force is assumed to act at a point 2h/3 down from the water surface. This force can be significantly intensified if perimeter enclosures are installed since the distance h is then measured to the bottom of the enclosure.

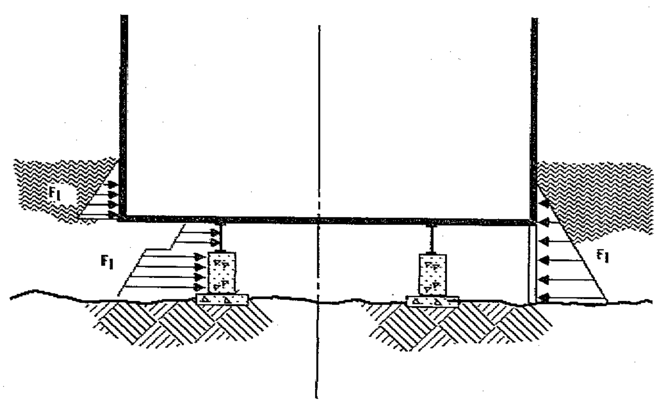


Figure 4.5 Lateral Forces

For example, if a manufactured home without perimeter enclosures was submerged in water to a point two feet above the bottom of the chassis I-beams, the resulting lateral force would be 124.8 pounds per linear foot. For a 60-foot long manufactured home, this translates into nearly four tons of pressure.

Table 4.1 provides the total lateral forces and point at which they act (center of gravity) for various water depths. The shaded areas in the table, corresponding to water column heights greater than or equal to 12 inches, highlight where these forces become overly excessive and exceed the design capacity of a manufactured home. Consequently, further elevation should be considered.

Buoyancy

In backwater or no-flow conditions, the critical hydrostatic force on a manufactured home is buoyancy which is dependent upon the difference in water height inside and outside the manufactured home as shown in Figure 4.6. As the manufactured home is raised above grade, the flood depth relative to the manufactured home floor elevation will decrease, as will the buoyancy force.

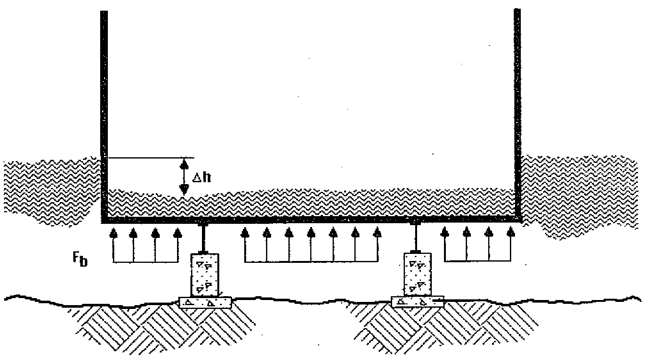


Figure 4.6 Buoyancy Forces

Elevating the home above potential flood levels is the only practicable method for eliminating all anticipated buoyancy forces on the manufactured home.

The buoyancy force is related to the weight of water and height of water displacement and is calculated as follows:

$$F_b = w \times \Delta h$$

Where:

F_b = Buoyancy force in pounds per square foot

w = Weight of water—62.4 pounds per cubic foot

Δh = Difference in height of water column inside and outside in feet

Buoyancy is equal to the weight of water times the difference in water height outside and inside the submerged surface. Water one foot above the bottom of an unflooded manufactured home interior would yield a buoyancy force of one foot × 62.4 pounds per cubic foot or 62.4 psf as shown in Figure 4.7. When the buoyancy force is greater than the weight of a manufactured home, which is approximately 20 pounds per square foot of floor area, the capacity of a conventional anchoring system is exceeded and flotation can occur. In view of these force considerations, manufactured homes must be elevated above anticipated flood levels.

Table 4.1

LATERAL FORCES (F_ℓ)

(pounds per linear foot of home length)

	Height of Water Column (inches)													
	1	2	3	4	5	6	9	12	15	18	24	30	36	48
F_ℓ	0.22	0.87	1.95	3.47	5.42	7.80	17.55	31.20	48.75	70.20	124.80	195.00	280.80	499.20
c	0.66	1.33	2.00	2.67	3.33	4.00	6.00	8.00	10.00	12.00	16.00	20.00	24.00	32.00

F_ℓ = $1/2\ w \times h^2$ (lb./lin. ft. of home)

Where:

w = 62.4 lb./cu.ft.

h = height of water column in feet, and

c = center of gravity in inches through which F_ℓ acts (2h/3) measured down from water surface.

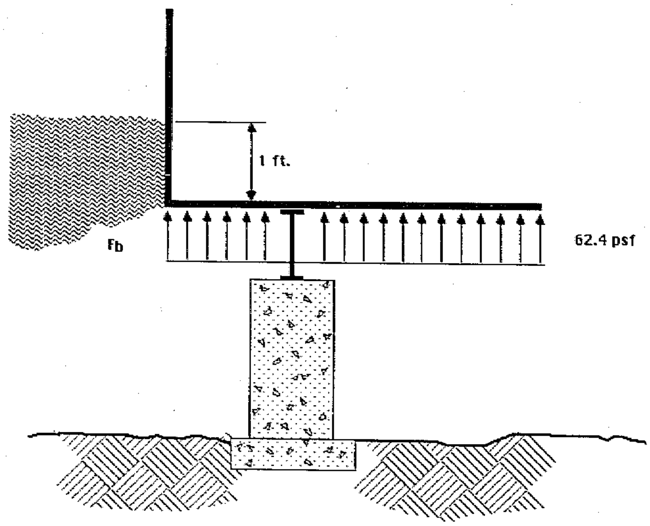


Figure 4.7 Buoyancy Force

Based on a manufactured home weight of 20 pounds per square foot of floor area, it is possible to determine the net buoyancy forces associated with differences in floodwater height.

Table 4.2 is the gross buoyancy force (F_b) exerted per foot length of the manufactured home due to a particular difference in anticipated water depth (h) inside and outside the manufactured home.

The Table includes up to 48 inches of water height difference for the purposes of highlighting the magnitude of forces. Based on the floor design capacity, any buoyancy above a nine to 12 inch water height differential can cause the floor decking to pull off the floor joists, thereby causing water inundation into the home. Those areas in the tables are shaded to highlight the practical limits in relation to buoyancy and the need to consider additional elevation.

The risk of flotation is largely dependent on the rate of water rise. With a fast rise, there is insufficient time for water to seep into the manufactured home, resulting in flotation from increased buoyancy forces. In slow rising flood conditions, floodwater can enter the manufactured home at a rate more equal to the water rise, thereby counteracting any buoyancy forces but causing substantial inundation damage. Elevation above anticipated flood levels is again highly important to minimize damage to the manufactured home.

Hydrodynamic Forces

Hydrodynamic forces are those imposed on any object which restricts a moving fluid. In the case of a manufactured home, hydrodynamic forces are caused by floodwater impact against the manufactured home and foundation. **Drag forces**, as shown in Figure 4.8, are one type of hydrodynamic force and are dependent upon the velocity of the floodwater, the drag coefficient of the surface restricting the flow and the depth to which the surface is submerged.

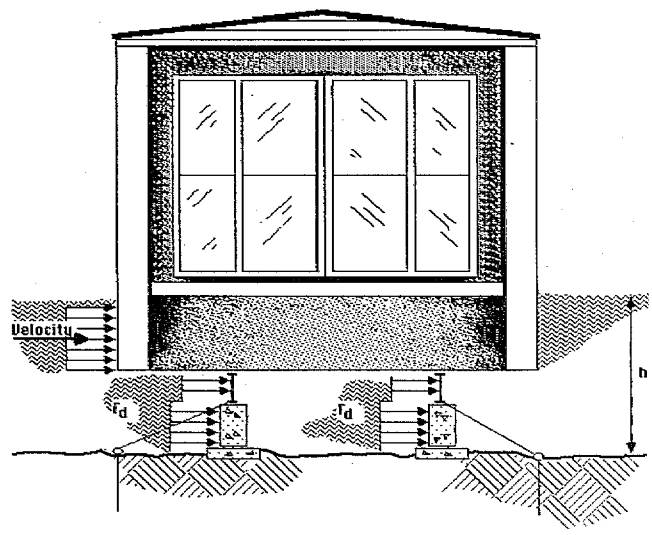


Figure 4.8 Drag Forces

Table 4.2

BUOYANCY FORCES (F_b)

Home Width (ft.)	Difference in water height inside and outside the manufactured home (in.)														
	1	2	3	4	5	6	9	12	15	18	21	24	30	36	42	48
12	62.4	124.8	187.2	249.6	312.0	374.4	561.6	748.8	936.0	1123.2	1310.4	1497.6	1872.0	2246.4	2620.8	2995.2
14	92.8	145.6	218.4	291.2	364.0	436.8	655.2	873.6	1092.0	1310.4	1528.8	1749.2	2184.0	2620.8	3057.6	3494.4
24	124.8	249.6	374.4	499.2	624.0	748.8	1123.2	1497.6	1872.0	2246.4	2620.8	2995.2	3744.0	4492.8	5241.6	5990.4
28	145.6	291.2	436.8	582.4	728.0	873.6	1310.4	1747.2	2184.0	2620.8	3057.6	3494.4	4368.9	5241.6	6115.2	6988.8

F_b = h x v x W (lb./lin. ft. of home)

Where: h = (h_1-h_2) ft.; v = 62.4 lb./cu. ft.; W = width (ft.)

Drag forces are calculated as follows:

$$F_d = \frac{C_d \times A \times \varrho \times V^2}{2}$$

Where:
- F_d = Drag force in pounds
- C_d = Coefficient of drag—1.31 for a manufactured home
- ϱ = Mass density of water—1.94 slugs per cubic foot
- V = Floodwater velocity in feet per second
- A = Projected vertical area submerged in square feet, including the chassis I-beam

For example a 60 foot long manufactured home submerged in six inches of water having a velocity of five feet per second acting on the side of the manufactured home chassis I-beam, as shown in Figure 4.9, would be impacted by the following drag force:

$$F_d = \frac{1.31 \times (60 \times 0.5) \times 1.94 \times (5)^2}{2} = 953 \text{ pounds}$$

Note that the bottom of the chassis I-beam is the point at which drag forces initially occur. Since the drag force is uniform over the side of the manufactured home, the drag force per square foot can be determined as follows:

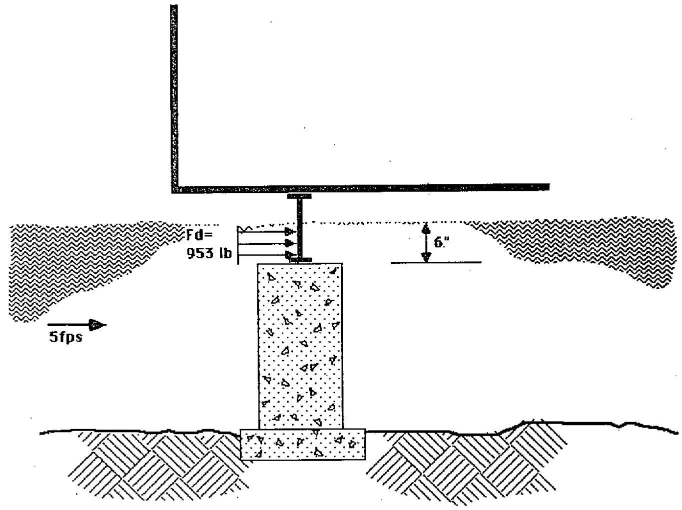


Figure 4.9 Drag Force

$$\frac{953 \text{ pounds}}{(60 \text{ ft.} \times 0.5 \text{ ft.})} = 31.77 \text{ psf.}$$

Table 4.3 provides drag forces as a function of water velocity and height. Areas in the table where drag forces exceed the capability of a manufactured home design are shaded.

Table 4.3

DRAG FORCES (F_d)
(pounds per linear foot of home length)

V (fps)	Water Height (in.) 1	2	3	4	5	6	9	12	15	18	24	30	36	48
1.0	.11	.21	.32	.42	.53	.64	.95	1.27	1.59	1.91	2.54	3.18	3.81	5.08
2.0	.42	.85	1.27	1.69	2.12	2.54	3.81	5.08	6.35	7.62	10.17	12.71	15.25	20.33
3.0	.95	1.91	2.86	3.81	4.77	5.72	8.58	11.43	14.30	17.15	22.87	28.59	34.31	45.75
4.0	1.69	3.39	5.08	6.78	8.47	10.17	15.25	20.33	25.41	30.50	40.66	50.83	60.99	81.32
5.0	2.65	5.29	7.94	10.59	13.24	15.88	23.83	31.77	39.71	47.65	63.54	79.42	95.30	127.07
6.0	3.81	7.62	11.44	15.25	19.06	22.87	34.31	45.75	57.18	68.62	91.49	114.36	137.24	182.98
8.0	6.78	13.55	20.33	27.11	33.89	40.66	60.99	81.32	101.66	121.99	162.65	203.31	243.97	325.30
10.0	10.59	21.18	31.77	42.36	52.94	63.54	95.30	127.07	158.84	190.61	254.14	317.68	381.21	508.28
12.0	15.25	30.50	45.75	60.99	76.24	91.49	137.24	182.98	228.73	274.47	365.96	457.45	548.94	731.92
15.0	23.83	47.65	71.48	95.30	119.13	142.95	214.43	285.91	357.38	428.86	571.82	714.77	857.72	1143.63

$F_d = \frac{1.31 \times A \times 1.94 \times V^2}{2}$ (lb./lin. ft. of home)

Where: A = projected submerged vertical area in square feet
V = floodwater velocity in feet per second

If, for example, one foot of water depth flowing at six feet per second were anticipated, the drag force would be 45.75 pounds per foot of length.

As the water velocity increases, the drag force will increase significantly because of the V^2 term in the equation. In the above example note that a doubling of velocity from six fps to 12 fps yields a drag force four times as great or 182.98 pounds per square foot of impacted area.

Drag forces due to water impacting the manufactured home can impose a significant increase in the loads on an elevated foundation. For this reason the manufactured home must be elevated above anticipated flooding. In addition, drag forces will affect any manufactured home foundation enclosure and transfer the drag forces to the elevated foundation. Provisions for allowing water to flow under the manufactured home should, therefore, be employed to reduce drag forces. In some higher velocity situations, any manufactured home foundation enclosure should be designed to break away before the forces cause overloading or failure of the elevated foundation system.

Another important consideration is the difference in height of the water upstream and downstream of the manufactured home. Water height will be greater on the upstream side; subsequently, the buoyancy and lateral forces will be greater on the upstream side. This imbalance of forces on the manufactured home will create a tendency for the manufactured home to overturn as shown in Figure 4.10.

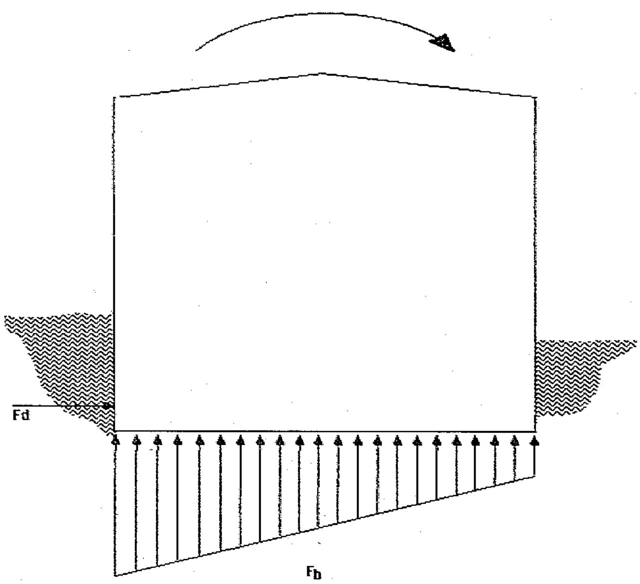


Figure 4.10 Overturning

The difference in height between the upstream and downstream side of the home is dependent upon water velocity and the position of the manufactured home in relation to flow. If the manufactured home is placed parallel to the flow as shown in Figure 4.11, the drag forces are reduced due to a smaller area being exposed to flow, thereby reducing the tendency for the manufactured home to overturn.

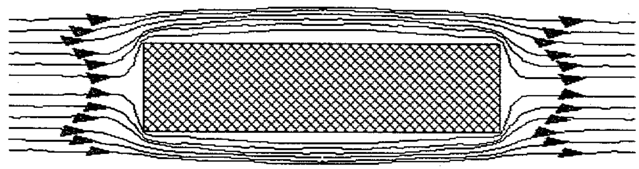


Figure 4.11 Parallel to Flow

If the manufactured home is placed perpendicular to flow, the area of the manufactured home affected by the flow, as shown in Figure 4.12, increases as do the resulting drag force and the height differential between upstream and downstream flow.

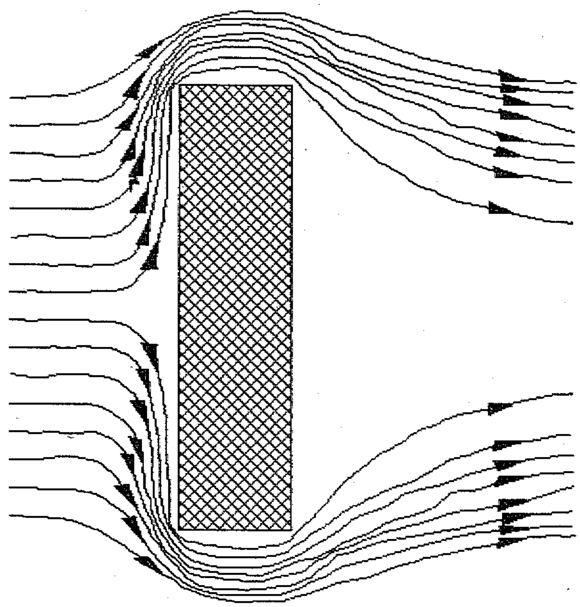


Figure 4.12 Perpendicular to Flow

Due to lack of data available on height differential related to flow velocity, manufactured home size and position in relation to flow, no specific calculations or design techniques can be offered. **If, however, the manufactured home is elevated such that floodwaters are not expected to reach the manufactured home, any tendency to overturn will be eliminated.** It is important to note, however, that an elevated manufactured home must be anchored to the elevating foundation or ground to prevent overturning from wind.

Impact Forces

Impact forces occur due to floating debris, ice, and other water-borne objects hitting the manufactured home or elevated foundation as shown in Figure 4.13. The magnitude of these forces will be dependent upon the mass of debris and the velocity of the water in which they are carried.

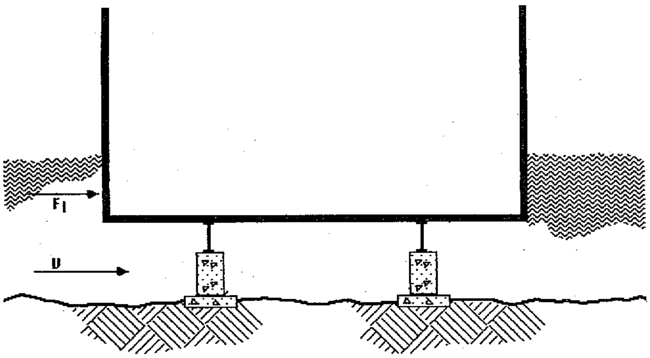


Figure 4.13 Impact Forces

Impact forces are calculated as follows:

$$F_i = \frac{m \times dV_b}{dt}$$

Where: F_i = impact force in pounds

m = mass of the water displaced by the object in slugs

V_b = velocity of the object in feet per second

t = time in seconds

$\frac{dV_b}{dt}$ = acceleration (deceleration) of the object in feet per second squared

The impact force acts horizontally at the flood level and can be assumed to be the impact force produced by a 1000 pound object traveling at the velocity of the floodwater and acting on one square foot of the manufactured home or elevated foundation. It can be assumed that the velocity of the object goes to zero in one second and the Impact Force equation can be restated as:

$$F_i = 31 \times V_b$$

Table 4.4 provides impact forces as a function of water velocity. For instance, at a velocity of 10 feet per second the impact force would be 310 pounds acting on one square foot of surface.

Table 4.4

IMPACT FORCES (F_i)
(Pounds per square foot)

Velocity (fps)										
1	2	3	4	5	6	7	8	9	10	15
31	62	93	124	155	186	217	248	279	310	465

$F_i = 31 \times V_b$ (lb./sq. ft.)

Where: V_b = velocity of the object in feet per second

Where floating debris is anticipated, the impact force on the manufactured home elevated foundation must also be taken into account in the design. Since the manufactured home itself is not designed to withstand these forces, the importance of elevating above anticipated flood depths is again apparent.

Scour

Scour is an important consideration for the manufactured home elevated foundation.

The calculation for determining scour depth at the elevated foundation members as shown in Figure 4.14 is based on their shape and width as well as the water velocity, water depth, and type of soil.

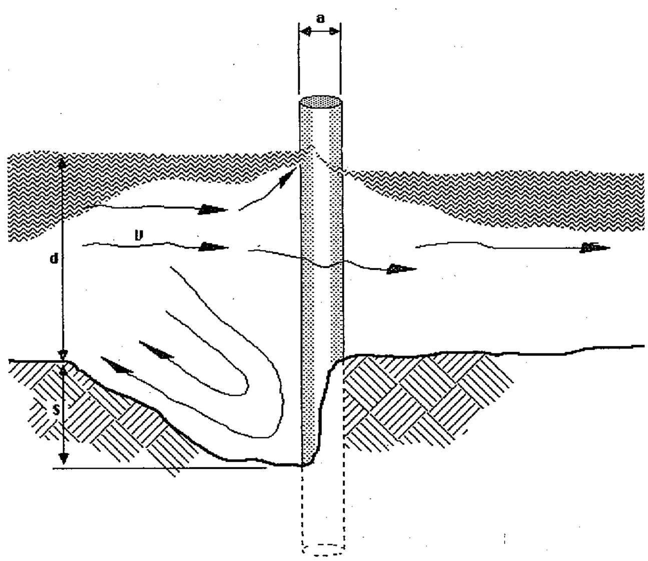


Figure 4.14 Scour

The scour depth at square and circular piers, posts, and piles can be calculated as follows:

$$S = d\left[2.2\left(\frac{a}{d}\right)^{0.65} \times \left(\frac{V}{\sqrt{gd}}\right)^{0.43}\right]$$

Where: S = depth of scour hole in feet

d = depth of flow upstream of structure in feet

a = diameter of post, pier, or pile in feet

V = velocity of flow approaching the structure in feet per second

g = acceleration of gravity—32.2 feet per second squared

Table 4.5 has been prepared for numerous velocity and depth values and typical vertical member diameters and applies to average soil conditions (2,000-3,000 psf bearing capacity). For loose sand and hard clay, the values may be increased and decreased respectively. However, the assistance of a soils engineer should be sought where highly erodable soil conditions exist (e.g. loose sand) or where scour depth values lower than those provided in Table 4.5 are used. In reviewing the scour depths in Table 4.5, note their magnitude and potential impact on piers which are placed on grade.

Table 4.5

DEPTH OF SCOUR (feet)

Velocity (fps)	Vertical Member Diameter (in.)				
	4	6	8	10	12
1	.75	1.00	1.25	1.50	1.75
2	1.00	1.25	1.50	1.75	2.00
4	1.50	1.75	2.00	2.25	2.75
6	1.75	2.00	2.50	2.75	3.25
8	2.00	2.25	2.75	3.25	3.50
10	2.25	2.50	3.00	3.50	4.00
15	2.50	3.00	3.50	4.00	4.50

The determination of maximum potential scour is critical in designing an elevated foundation system to ensure that failure during and after flooding does not occur due to any loss in bearing capacity or anchoring resistance around the posts, piles, or piers elevating the manufactured home. The anticipated scour depth must, therefore, be added to the preflood height above grade in determining the necessary post, pile, or pier design as shown in Figure 4.15. Without the inclusion of scour depth in elevated foundation design, failure and collapse of the foundation system is more likely after a flood.

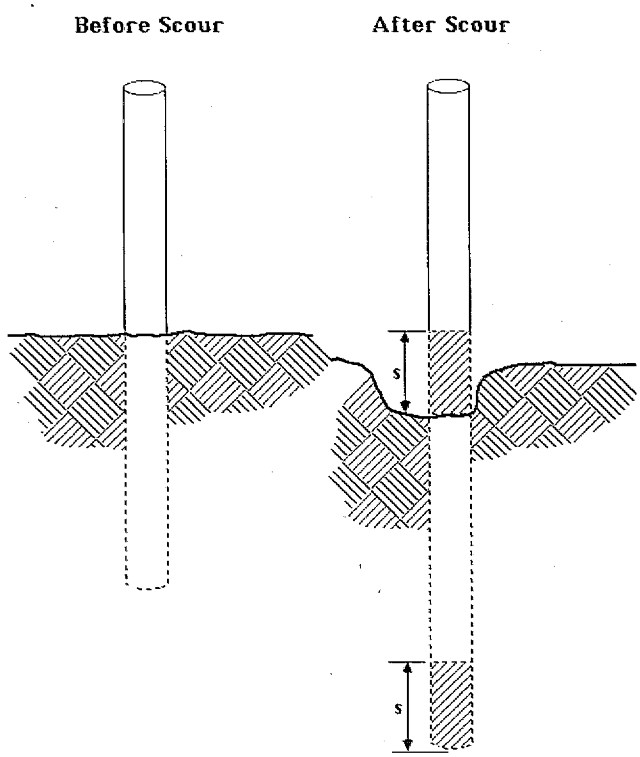


Figure 4.15 Addition of Scour Depth

In coastal areas scour depths can be significant due to both localized scour as calculated above and area erosion resulting from the overall effects of storm surge. Since area erosion is difficult to predict, local regulatory officials should be contacted for further information and historical perspectives.

Based upon the water velocity and type of soil, scour and erosion would increase the height above grade of the vertical member since the grade level would be reduced due to scour and erosion. As this occurs, the depth of burial of the vertical member also decreases an identical distance. This can result in an elevated foundation failure because the loss of natural supporting soils would change the conditions under which the elevated foundation system was designed.

To account for this, the vertical member length used for the purpose of determining an acceptable design must be increased. This vertical member length is used in Section B of this chapter in determining the size of the vertical member needed to carry anticipated loading.

For example, consider an area where a manufactured home is to be placed on a six foot high foundation using eight inch posts. If the anticipated flood velocity was six fps, the scour depth from Table 4.5 is 30 inches. For the purpose of determining the necessary post length, the scour depth of 30 inches would be included in the vertical member length as shown in Figure 4.16.

Design Loads

Design loads (roof live, wind, dead, floor live) which are over and above those caused by flooding, must also be considered in that any elevated foundation design must be capable of also withstanding these loads. The magnitude of these loads is shown in Tables 4.6 to 4.9 and will be used in the evaluation of elevated foundation design strategies. Note that roof live loads and wind loads are *not* additive. Hence, the elevated foundation design must be based on the greater of these loads.

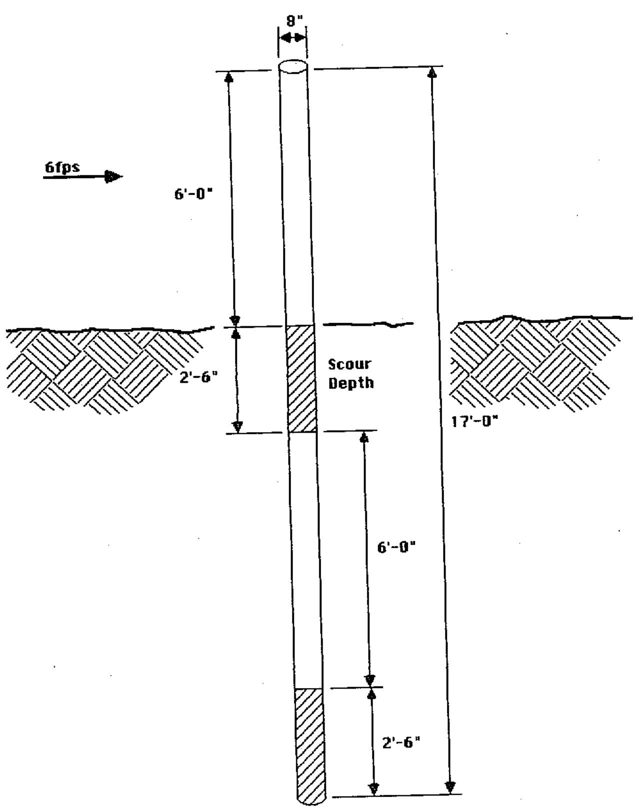


Figure 4.16 Addition of Scour Depth

Table 4.6

BUILDING LOADS (pounds)
12 Foot Wide Manufactured Home

	Length (feet)[1]							
	32	40	48	52	56	60	66	72
Roof Live[2]								
20 psf	9520	11760	14000	15120	16240	17360	19040	20720
30 psf	14280	17640	21000	22680	24360	26040	28560	31080
40 psf	19040	23520	28000	30240	32480	34720	38080	41440
Dead[3]	7680	9600	11520	12480	13440	14400	15840	17280
Floor Live[4]	15360	19200	23040	24960	26880	28800	31680	34560
Wind[5] (Lateral)								
15 psf	4680	5850	7020	7605	8190	8775	9653	10550
25 psf	7800	9750	11700	12675	13650	14625	16088	17550
Wind[6] (Uplift)								
9 psf	5526	6750	7974	8586	9198	9810	10728	11646
15 psf	9210	11250	13290	14310	15330	16350	17880	19410

1. Length refers to the "box" length of the manufactured home.
2. Roof live loads based upon roof area including a one foot roof eave around the manufactured home perimeter.
3. Dead loads based upon gross floor area and 20 psf design load.
4. Floor live loads based upon gross floor area and 40 psf design load.
5. Wind loads (lateral) based upon windward longitudinal wall area (9.75' x length') and stated wind force.
6. Wind loads (uplift) based upon roof area including a one foot eave around the manufactured home perimeter. A 2.5 wind load factor is applied to the one foot eave.

Table 4.7

BUILDING LOADS (pounds)
14 Foot Wide Manufactured Home

	Length (feet)[1]							
	32	40	48	52	56	60	66	72
Roof Live[2]								
20 psf	10880	13440	16000	17280	18560	19840	21760	23680
30 psf	16320	20160	24000	25920	27840	29760	32640	35520
40 psf	21760	26880	32000	34560	37120	39680	43520	47360
Dead[3]	8960	11200	13440	14560	15680	16800	18480	20160
Floor Live[4]	17920	22400	26880	29120	31360	33600	36960	40320
Wind[5] (Lateral)								
15 psf	4680	5850	7020	7605	8190	8775	9653	10530
25 psf	7800	9750	11700	12675	13650	14625	16088	17550
Wind[6] (Uplift)								
9 psf	6192	7560	8928	9612	10296	10980	12006	13032
15 psf	10320	12600	14880	16020	17160	18300	20010	21720

1. Length refers to the "box" length of the manufactured home.
2. Roof live loads based upon roof area including a one foot roof eave around the manufactured home perimeter.
3. Dead loads based upon gross floor area and 20 psf design load.
4. Floor live loads based upon gross floor area and 40 psf design load.
5. Wind loads (lateral) based upon windward longitudinal wall area (9.75' x length') and stated wind force.
6. Wind loads (uplift) based upon roof area including a one foot eave around the manufactured home perimeter. A 2.5 wind load factor is applied to the one foot eave.

Table 4.8

BUILDING LOADS (pounds)
24 Foot Wide Manufactured Home

	Length (feet)[1]				
	40	48	52	56	60
Roof Live[2]					
20 psf	21840	26000	28080	30160	32240
30 psf	32760	39000	42120	45240	48360
40 psf	43680	52000	56160	60320	64480
Dead[3]	19200	23040	24960	26880	28800
Floor Live[4]	38400	46080	49920	53760	57600
Wind[5] (Lateral)					
15 psf	5850	7020	7605	8190	8775
25 psf	9750	11700	12675	13650	14625
Wind[6] (Uplift)					
9 psf	11610	13698	14742	15786	16830
15 psf	19350	22830	24570	26310	28050

1. Length refers to the "box" length of the manufactured home.
2. Roof live loads based upon roof area including a one foot roof eave around the manufactured home perimeter.
3. Dead loads based upon gross floor area and 20 psf design load.
4. Floor live loads based upon gross floor area and 40 psf design load.
5. Wind loads (lateral) based upon windward longitudinal wall area (9.75' x length') and stated wind force.
6. Wind loads (uplift) based upon roof area including a one foot eave around the manufactured home perimeter. A 2.5 wind load factor is applied to the one foot eave.

Table 4.9

BUILDING LOADS (pounds)
28 Foot Wide Manufactured Home

	Length (feet)[1]				
	40	48	52	56	60
Roof Live[2]					
20 psf	25200	30000	32400	34800	37200
30 psf	37800	45000	48600	52200	55800
40 psf	50400	60000	64800	69600	74400
Dead[3]	22400	26880	29120	31360	33600
Floor Live[4]	44800	53760	58240	62720	67200
Wind[5] (Lateral)					
15 psf	5850	7020	7605	8190	8775
25 psf	9750	11700	12675	13650	14625
Wind[6] (Uplift)					
9 psf	13230	15606	16794	17982	19170
15 psf	22050	26010	27990	29970	31950

1. Length refers to the "box" length of the manufactured home.
2. Roof live loads based upon roof area including a one foot roof eave around the manufactured home perimeter.
3. Dead loads based upon gross floor area and 20 psf design load.
4. Floor live loads based upon gross floor area and 40 psf design load.
5. Wind loads (lateral) based upon windward longitudinal wall area (9.75' x length') and stated wind force.
6. Wind loads (uplift) based upon roof area including a one foot eave around the manufactured home perimeter. A 2.5 wind load factor is applied to the one foot eave.

For example, the building loads for a 14 ft. by 66 ft. manufactured home located in a 40 psf roof live load zone and 25 psf (lateral) and 15 psf (uplift) wind zone would be calculated as follows:

Roof Live Load = (width + 2 ft. eaves) × (length + 2 ft. eaves) × 40 psf = (14 + 2) × (66 + 2) × 40 psf = 43,520 pounds

Dead Load = (width × length) × 20 psf = (14 × 66) × 20 psf = 18,480 pounds

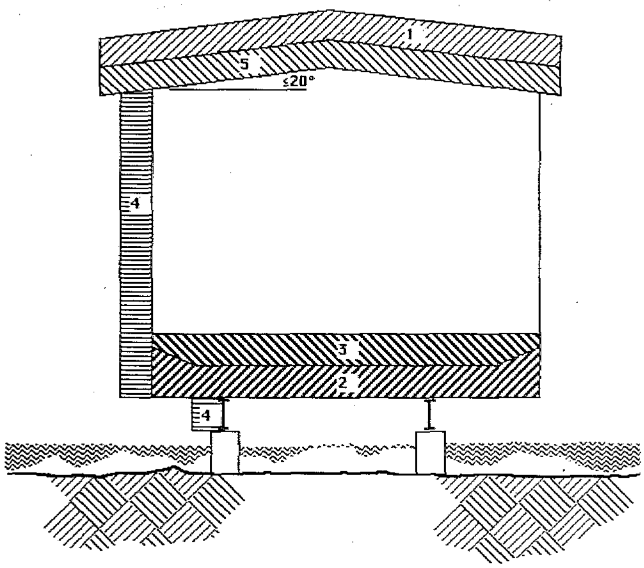
Floor Live Load = (width × length) × 40 psf = (14 × 66) × 40 psf = 36,960 pounds

Wind Load (lateral) = (height × length) × 25 psf = (9.75 ft. × 66 ft) × 25 psf = 16,088 pounds

Wind Load (uplift) = {[[(width + 2 ft. eaves) × (length + 2 ft eaves)] – [(width × length)]] × 2.5 × 15 psf} + (width × length) × 15 psf = {[[(14 + 2) × (66 + 2)] – [(14 × 66)]] × 2.5 × 15 } + (14 × 66) × 15 psf = 6150 pounds + 13860 pounds = 20,010 pounds

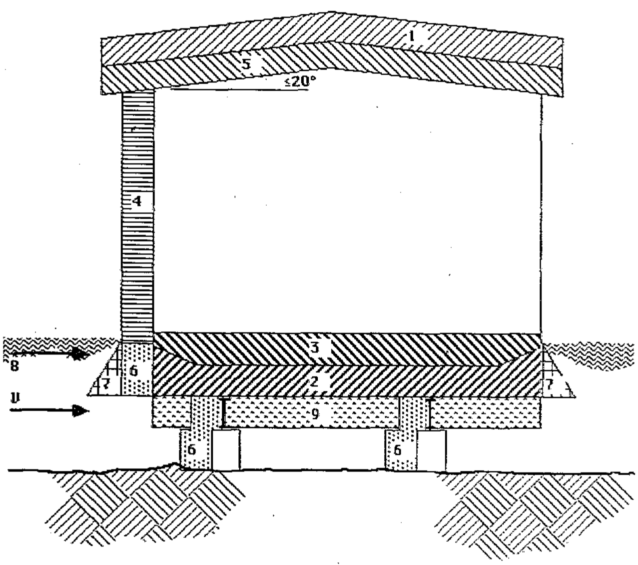
The flood and design loads, as shown in Figures 4.17 and 4.18, can be summarized and shown as follows:

FORCE	VALUE	IMPACTED PORTIONS OF THE ELEVATED FOUNDATION
Roof Live Load	20, 30, or 40 psf of roof area	Vertical load affecting the foundation bearing capability, any horizontal support members and their connections.
Dead Load	20 psf of gross floor area	Vertical load affecting the foundation bearing capability, any horizontal support members and their connections.
Floor Live Load	40 psf of gross floor area	Vertical load affecting the foundation bearing capability, any horizontal support members and their connections.
Buoyancy	62.4 $lb./ft.^3$ × height differential inside/outside home	Vertical load affecting floor capacity, anchoring of structure, capacity of the foundation system and connections.
Wind (uplift)	9 or 15 $lb./ft.^2$ × (roof area + 1 ft. eaves at 2.5 × load)	Vertical load affecting floor capacity, anchoring of structure, capacity of the foundation system and connections.
Lateral (flood)	31.2 $lb./ft.^3$ × (height of water column acting on vertical surface)^2	Horizontal load affecting the wall capacity, anchoring of structure, foundation design and connections.
Lateral (wind)	15/25 $lb./ft.^2$ × (windward longitudinal wall area)	Horizontal load affecting the wall capacity, anchoring of structure, foundation design and connections.
Drag	1.2707 × (velocity)^2 × height of water column on the vertical surface	Horizontal load affecting the wall capacity, anchoring of structure, foundation design and connections.
Impact	31 × flood velocity	Horizontal load affecting the wall capacity, anchoring of structure, foundation design and connections.



1. Roof Live Load
2. Dead Load
3. Floor Live Load
4. Wind Load (lateral)
5. Wind Load (uplift)

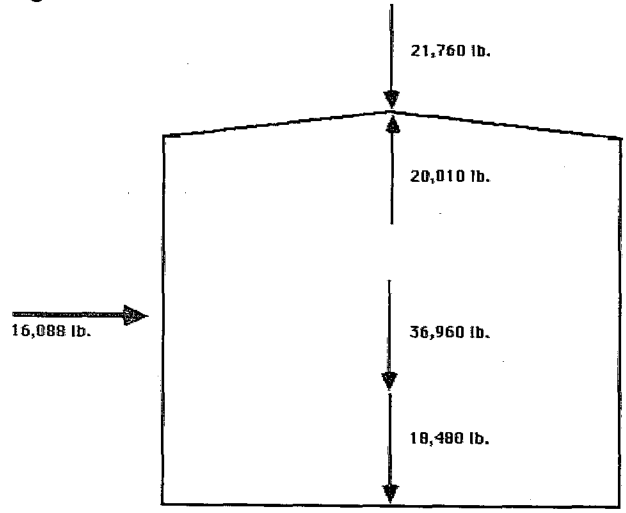
Figure 4.17 Home Elevated Above Flood Waters



1. Roof Live Load
2. Dead Load
3. Floor Live Load
4. Wind Load (lateral)
5. Wind Load (uplift)
6. Drag
7. Lateral
8. Impact
9. Buoyancy

Figure 4.18 Home Not Elevated Above Flood Waters

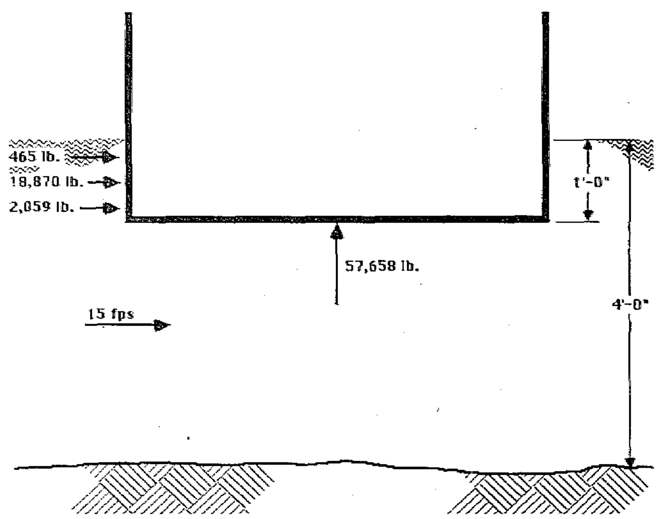
For example, a 14 ft. by 66 ft. manufactured home not impacted by flooding and located in eastern North Carolina (southern roof live load zone and hurricane wind zone) would have the following loads as shown in Figure 4.19. Note again roof live and wind loads are *not* additive.



1. Roof Live Load	=	21,760 lbs.
2. Dead Load	=	18,480 lbs.
3. Floor Live Load	=	36,960 lbs.
4. Wind Load (lateral)	=	16,088 lbs.
5. Wind Load (uplift)	=	20,010 lbs.

Figure 4.19 Design Loads

In the above situation with the floor of the manufactured home located three feet above grade and impacted with a four foot water depth above grade (that is, one foot of water depth acting on the manufactured home) at 15 feet per second the following flood forces as shown in Figure 4.20 would also occur.



6. Drag	=	18,870 lbs.
7. Total Lateral Load	=	2,059 lbs.
8. Impact	=	465 psf
9. Buoyancy	=	57,658 lbs.

Figure 4.20 Flood Loads

The following section provides calculational procedures and design methods which can be used to determine appropriate strategies to withstand or counteract these forces.

Note, as previously stressed, elevation of the manufactured home above anticipated flooding significantly reduces or eliminates the flood loading on the manufactured home. This, in turn, greatly enhances the probability for survival of a flood occurrence.

B. EVALUATION OF ELEVATED FOUNDATIONS

An elevated foundation must be adequately supported in the ground, tied effectively to the manufactured home, and have the ability to withstand flood and wind induced loads, dead loads, roof live loads, and floor live loads. As previously discussed, the imposition of hydrostatic, hydrodynamic, and impact forces on the manufactured home will add additional loads to the elevated foundation. The magnitude of these loads, as shown in Figure 4.21, is sufficient to seriously damage a manufactured home not elevated above anticipated flooding.

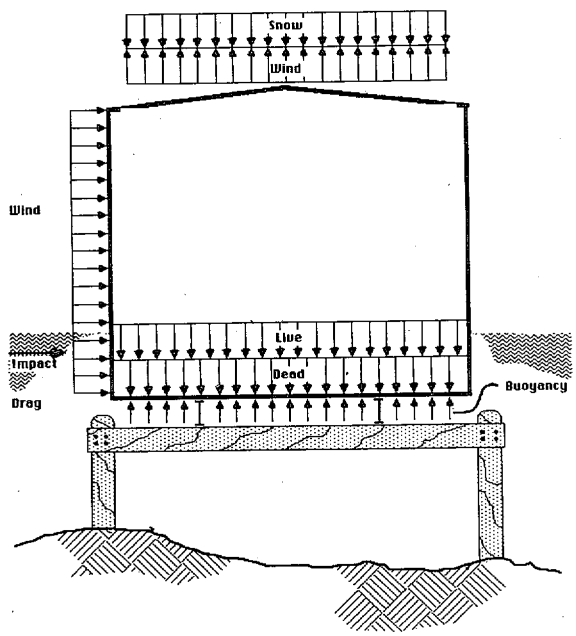


Figure 4.21 Magnitude of Loads

Ground anchors and tie-downs can hold the manufactured home in position **only under extremely low velocity and depth conditions** during flooding. From a design standpoint, the practical limitations on anchoring and tie-down to counteract flood forces can be summarized as follows:

Water Velocity	Tie Angle To Vertical	Maximum Flood Height Above Floor
0 to 5 fps	0	10″
	30	9″
	45	8″
5 to 10 fps	0	8″
	30	7″
	45	6″
10 fps	None—Manufactured home must be elevated above anticipated flooding.	

The above information indicates that flood heights of more than one foot will result in forces that cannot be effectively counteracted by ground anchors and tie-downs. Because of this, and also because even a small amount of depth above the floor can substantially damage a manufactured home, the use of anchoring alone, without additional elevation is not effective in minimizing future flood losses. **The optimum strategy is to elevate the manufactured home to a height where no flood forces are anticipated to affect the manufactured home.**

Appendix E provides additional details on ground anchor spacings necessary to resist buoyancy and drag forces and should be consulted for further information. A review of this appendix will serve to validate the limitations of ground anchoring and tie-downs in flooding conditions.

Piers, posts, and piles can be used to elevate a manufactured home above anticipated flood levels. When the manufactured home is elevated above anticipated flooding, flood forces act **only** on the elevated foundation. **The elevated foundation, however, must support the manufactured home, and withstand all other anticipated forces.**

As previously discussed, a registered design professional may be required to design the elevated foundation depending upon state or local regulations and the height above grade.

Design Forces and Loads

The flood forces to be considered in the design of an elevated foundation are buoyancy, lateral, impact, and drag forces as discussed in Section A of this chapter. Generally, when compared to forces imposed by wind, dead load, roof live load, and floor live load, the flood forces on the foundation are small if the manufactured home is elevated above the anticipated flood level. As the manufactured home elevation is increased, the non-flood forces on the elevated foundation are increased as shown in Figure 4.22. This affects the design of the elevated foundation.

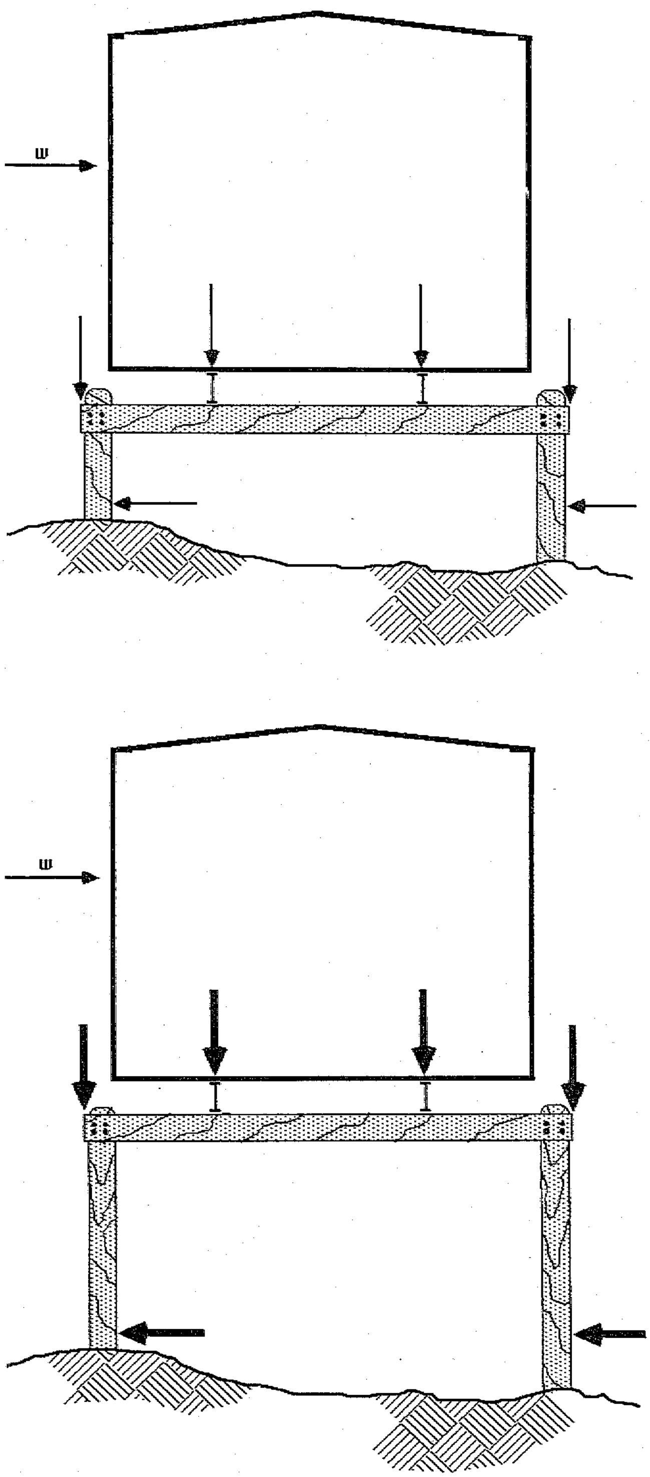
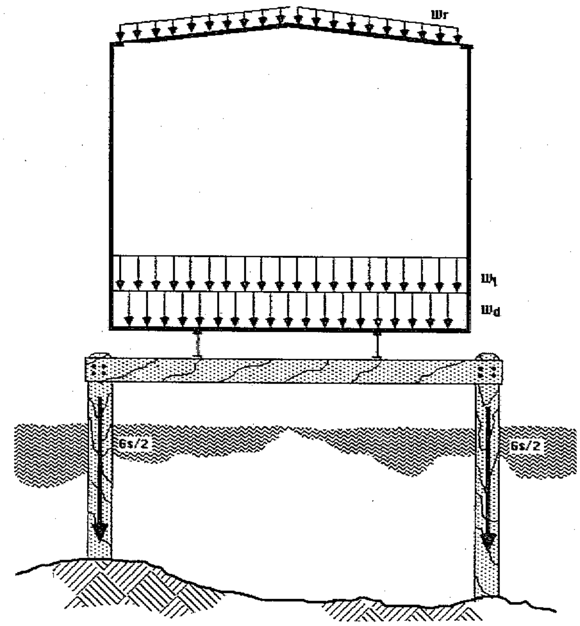


Figure 4.22 Forces Increase With Elevation

Figures 4.23 and 4.24 show the loads applied to an elevated foundation supporting a manufactured home.

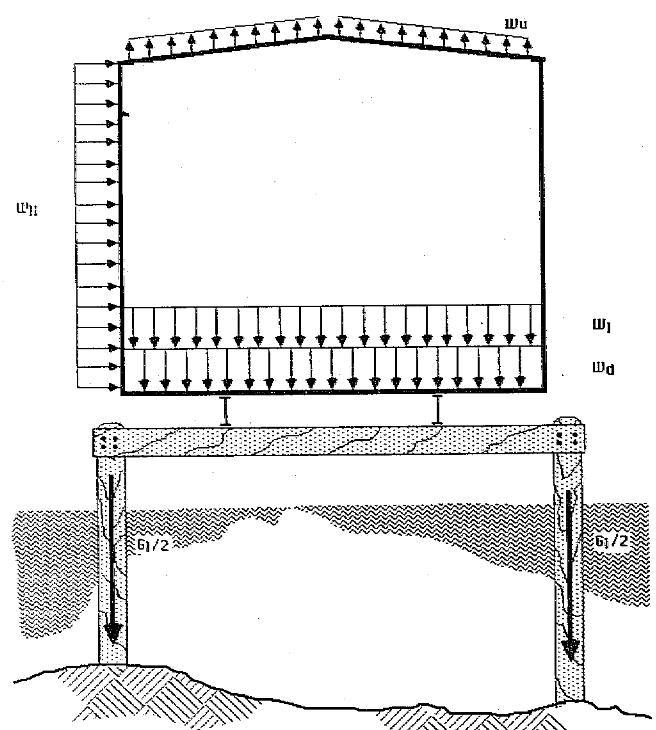


G_s = dead, floor live, and roof live loads associated with the manufactured home

W_d = dead load W_r = roof live load

W_ℓ = floor live load

Figure 4.23 Roof Dominated Loads



G_l = dead floor live and wind loads associated with the manufactured home

W_d = dead load $W_{\ell\ell}$ = wind load (lateral)

W_ℓ = floor live load

W_u = wind load (uplift)

Figure 4.24 Wind Dominated Loads

Table 4.10 provides the calculated maximum vertical loads for typical manufactured home widths (12 feet and 14 feet) and chassis I-beam spacing 75½-, 82-, and 99-inches based on the spacing of vertical members along the length of the manufactured home. The elevated foundation design must support these loads. Note that design roof live loads and wind loads *do not* occur simultaneously.

Because a double section manufactured home is essentially two connected single section manufactured homes, this chapter presents design criteria based on typical single section widths. When a double section manufactured home is being considered, the recommendations provided herein should be followed for each section.

Table 4.10

MAXIMUM VERTICAL MEMBER LOAD (pounds)

Longitudinal Spacing (ft.)	Manufactured Home Width (ft.)					
	12			14		
	Chassis I-Beam Spacing (in.)					
	75 1/2	82	99	75 1/2	82	99
Wind Load = 15 psf Roof Live Load = 20 psf						
5		2500			2900	
6		3000			3480	
7		3500			4060	
8		4000			4640	
9		4500			5220	
10		5000			5800	
Wind Load = 25 psf Roof Live Load = 20 psf						
5	2744	2669	2520	3044	2969	2900
6	3293	3203	3024	3653	3563	3480
7	3842	3737	3528	4262	4157	4060
8	4391	4271	4032	4871	4751	4640
9	4940	4805	4536	5480	5345	5220
10	5489	5339	5040	6089	5939	5800
Roof Live Load = 30 psf Wind Load = 15 or 25 psf						
5		2850			3300	
6		3420			3960	
7		3990			4620	
8		4560			5280	
9		5130			5940	
10		5700			6600	
Roof Live Load = 40 psf Wind Load = 15 or 25 psf						
5		3200			3700	
6		3840			4440	
7		4480			5180	
8		5120			5920	
9		5760			6660	
10		6400			7400	

For example, a 14-foot wide manufactured home having a 99-inch chassis I-beam spacing located in a 30 psf roof live load area and eight foot spacing of vertical support members has a 5,280 pound load at each point where the elevated foundation supports the manufactured home as shown in Figure 4.25.

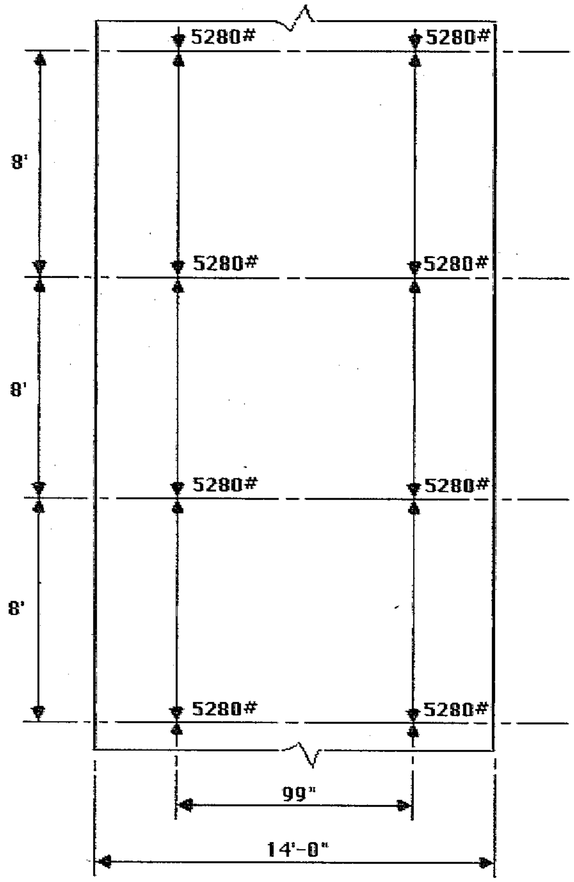


Figure 4.25 Vertical Member Load

The design of an elevated foundation to resist these loads is dependent on the specific elevation technique selected, height above grade, size of foundation components, connections, and spacing of supporting members lengthwise along the manufactured home. **Spacing of vertical members must not exceed the recommended spacing in the homeowner's installation manual or 10 feet, whichever is less.** In addition, any requirements for perimeter blocking in the homeowner's installation manual must also be completed.

Prior to selecting and designing a vertical member to elevate the manufactured home, the bearing capacity of the soil on the site must be determined. This is critical to assure that adequate support for any elevated foundation is provided by the soil.

Estimating the bearing capacity of soil is difficult in that soil characteristics may be altered later by a change in moisture content. Soil classification of a general nature can be shown as follows:

SOIL	BEARING PRESSURE (psf)
Clay, soft	600-1200
Clay, firm	1500-2500
Clay, stiff	3000-4500
Loose sand, wet	800-1600
Firm sand, wet	1600-3500
Packed earth	2700-3000
Loose earth	2300-2700
Gravel 1″	3000-3300
Gravel 2½″	2700-3000

In general soils can be divided into five classifications; very soft, poor, average, good, and very hard. Bearing capacities are respectively 800 - 1200 psf, 1200 - 2000 psf, 2000 - 3000 psf, 3000 - 4100 psf, and 4100+ psf.

Where a general visual inspection and consultation with a soils engineer is not sufficient to estimate the bearing capacity of the soil, a load test should be conducted. The load test should be conducted when the soil is wet.

After the soil bearing capacity is determined, that value can be evaluated against the maximum vertical member load to determine the required bearing area of the vertical member as follows:

$$\frac{\text{Vertical Member Load (lb.)}}{\text{Soil Bearing Capacity (psf)}} = \text{bearing area (sq. ft.)}$$

For example, if the previous example shown in Figure 4.25 was to be located where the soil bearing capacity was found to be 1800 psf, the required bearing area under each vertical member would be as follows:

$$\frac{5280 \text{ lb.}}{1800 \text{ psf}} = 2.93 \text{ sq. ft.}$$

A bearing pad 21 inches by 21 inches would be acceptable since it provides an area of 3.06 sq. ft.

The following sections provide details on the design of components needed to resist these loads under various conditions. These include vertical member (piers, posts and piles), horizontal supports, diagonal bracing, and connections associated with an elevated foundation design.

Vertical Support Members

Piers—Flood and wind loads are resisted by piers through their structural capacity. Cast-in-place concrete and built up concrete masonry unit or brick piers, because of their larger surface area and limited anchorage in the ground, are more susceptible to flood forces than posts or piles.

Consequently, they are more dependent on surface soil conditions than posts or piles and their performance is greatly affected by erosion and scour which undermines their stability upon which the elevated manufactured home is dependent. **The use of a pier system should, therefore, not be considered in areas where any flood velocity is anticipated.**

Piers can be used in backwater (no-flow) flood areas to elevate the manufactured home above the anticipated flood level. Where the required elevation is less than three feet to the bottom of the chassis I-beam, a conventional installation can be used as previously discussed.

Based on an analysis of anticipated loads and the capacity of various pier designs, Table 4.11 provides pier designs acceptable for elevating a manufactured home.

Based on the pier spacing along the length of the manufactured home and height of the pier, one or more acceptable pier designs is available. For other pier designs or conditions not addressed herein, Appendix D on design calculations can be consulted.

Pier Design A, as shown in Figure 4.26, consists of eight inch by eight inch cast-in-place concrete with four No. 4 steel reinforcement bars. Pier Design A is acceptable for the conditions labeled A as shown in Table 4.11, based on a minimum concrete strength of 2500 psi.

Pier Design B, as shown in Figure 4.27, consists of eight inch by 12 inch concrete masonry units (CMU) with four No. 4 steel reinforcement bars. Pier Design B is acceptable for the conditions labeled A or B as shown in Table 4.11 based on a minimum CMU strength of 1500 psi.

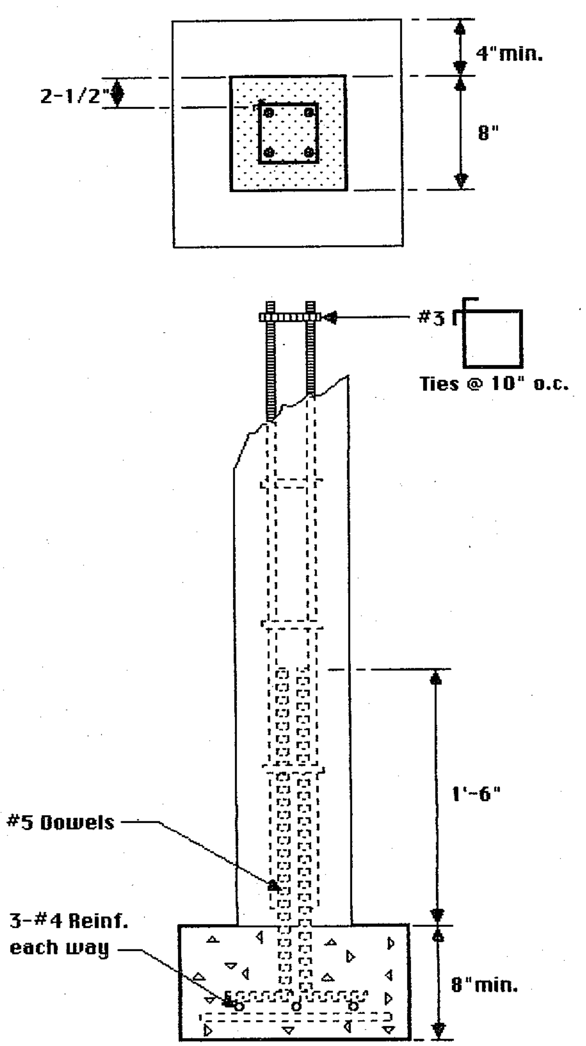


Figure 4.26 Pier Design A

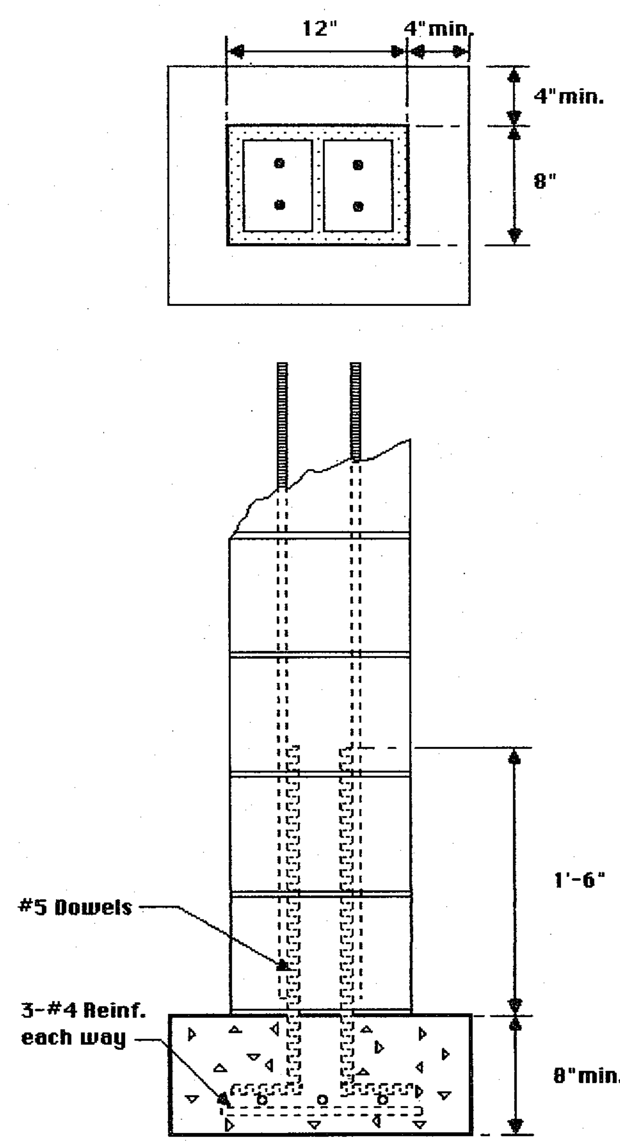


Figure 4.27 Pier Design B

Pier Design C, as shown in Figure 4.28, consists of eight inch by 16 inch concrete masonry units with four No. 5 steel reinforcement bars. Pier Design C is acceptable for the conditions labeled, A, B, or C, as shown in Table 4.11, based on a minimum CMU strength of 1500 psi.

Pier Design D, as shown in Figure 4.29, consists of 12 inch by 12 inch cast-in-place concrete or common brick with four No. 5 steel reinforcement bars. Pier Design D is acceptable for the conditions labeled A, B, C, or D as shown in Table 4.11, based on a minimum concrete strength of 2500 psi.

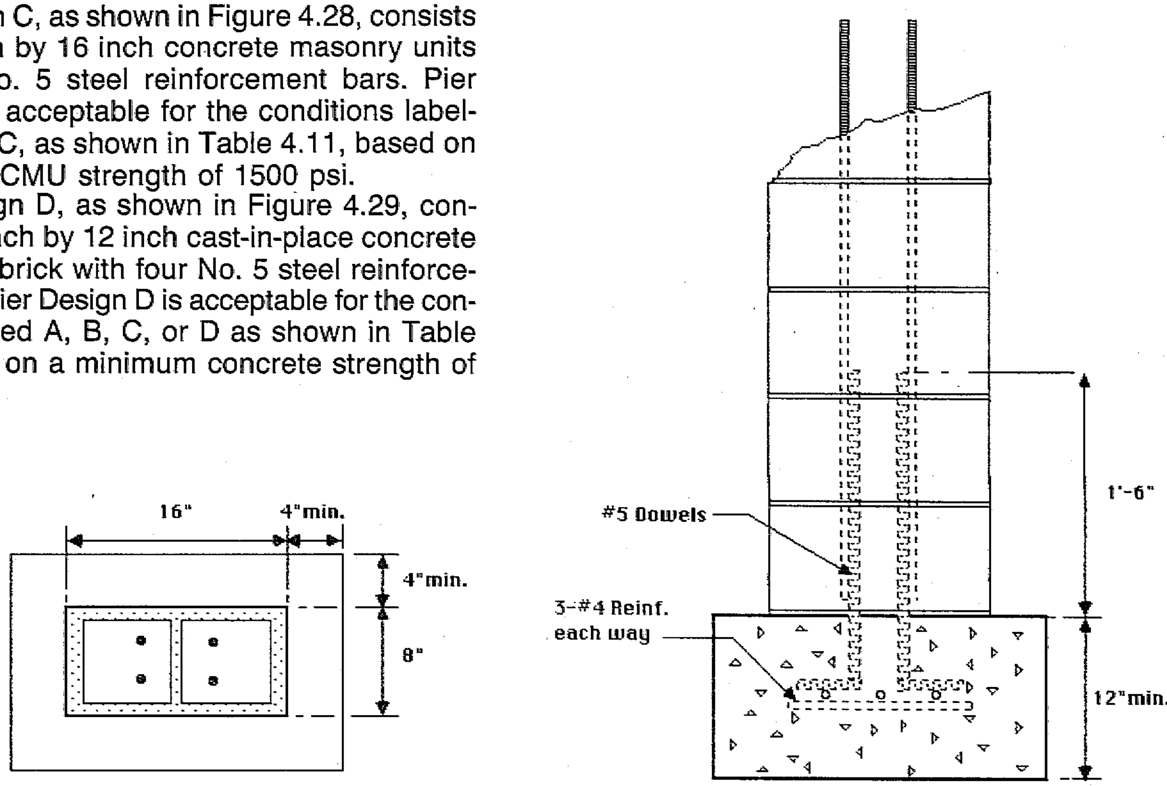
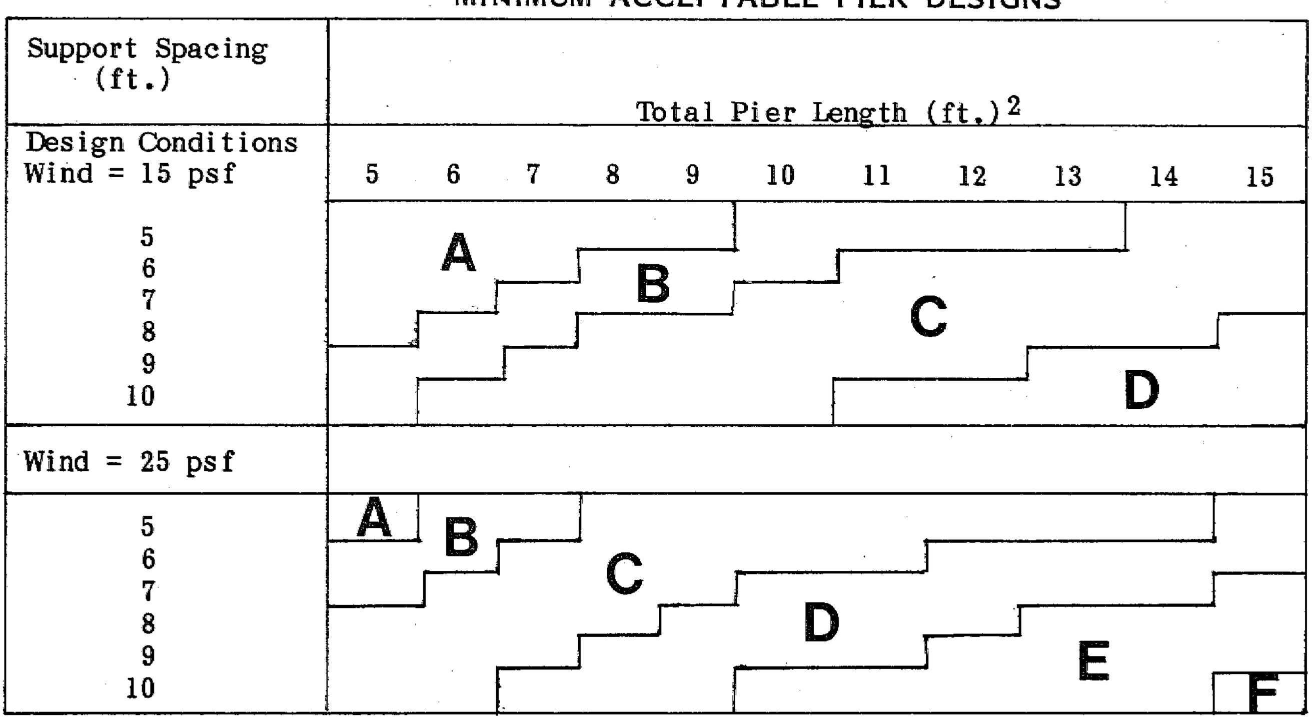


Figure 4.28 Pier Design C

Table 4.11

MINIMUM ACCEPTABLE PIER DESIGNS[1]



[1]Per manufactured home section
[2]Total pier length including depth below grade to the top of the footing.

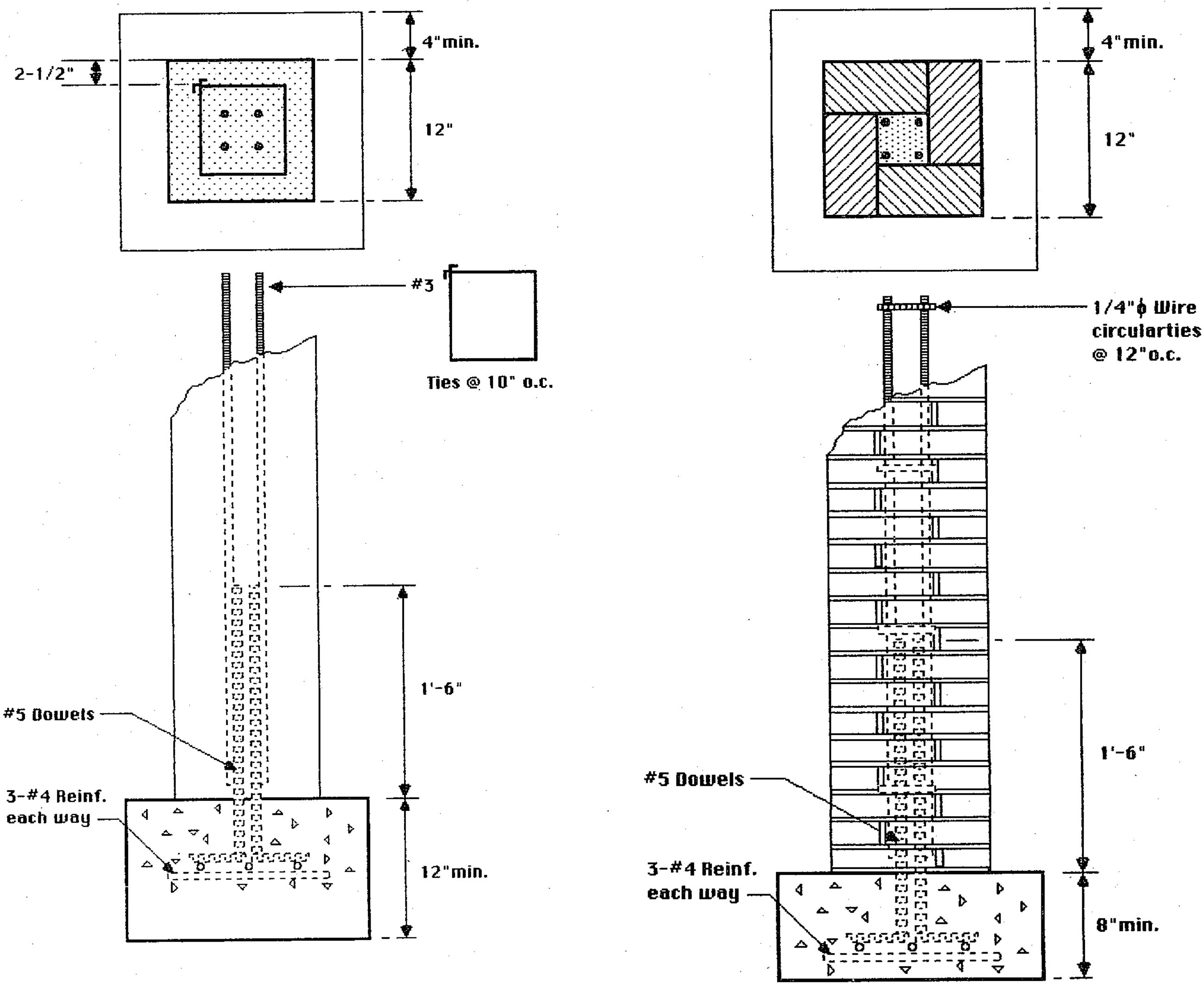


Figure 4.29 Pier Design D

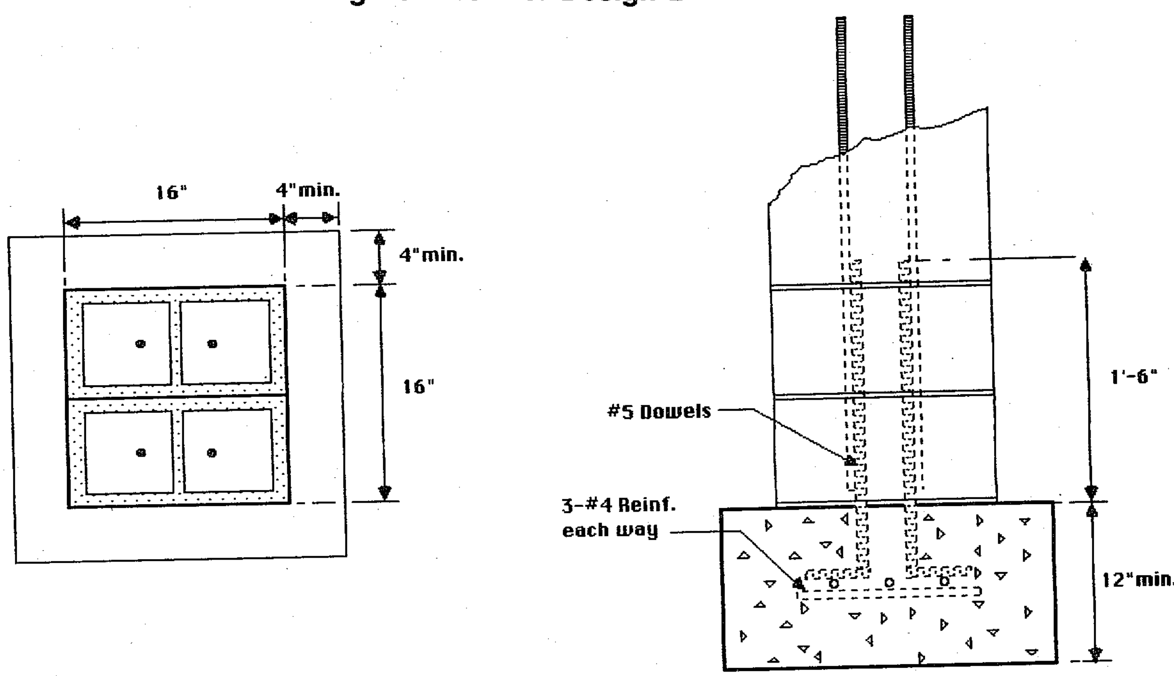


Figure 4.30 Pier Design E

Pier Design E, as shown in Figure 4.30, consists of 16 inch by 16 inch (two eight inch by 16 inch) concrete masonry units with four No. 5 steel reinforcement bars. Pier Design E is acceptable for the conditions labeled A, B, C, D, or E as shown in Table 4.11, based on a minimum CMU strength of 1500 psi.

Pier Design F, as shown in Figure 4.31, consists of 16 inch by 16 inch cast-in-place concrete with four No. 5 steel reinforcement bars. Pier Design F is acceptable for all conditions shown in Table 4.11, based on a minimum CMU strength of 1500 psi.

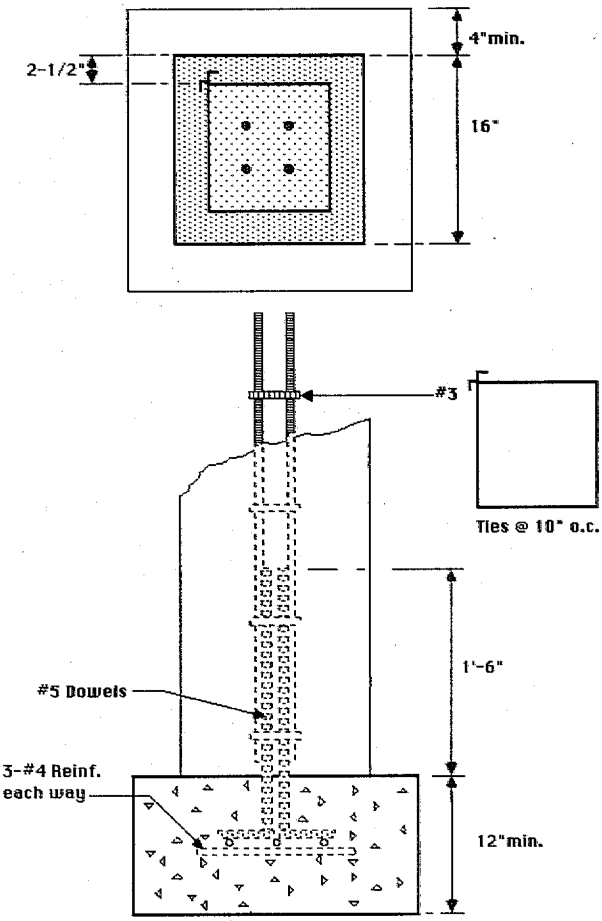


Figure 4.31 Pier Design F

Ground anchors, over and above those required in state anchoring regulations, must be provided as shown in Table 4.12. Ground anchor location should be between two and three feet from the pier toward the center of the manufactured home and installed as shown in Figures 4.32 and 4.33.

Table 4.12

GROUND ANCHOR SPACING

Wind Zone	Height Above Grade (ft.)									
	1	2	3	4	5	6	7	8	9	10
I (15 psf)	20 Foot on Center									
II (25 psf)						10 Foot on Center				

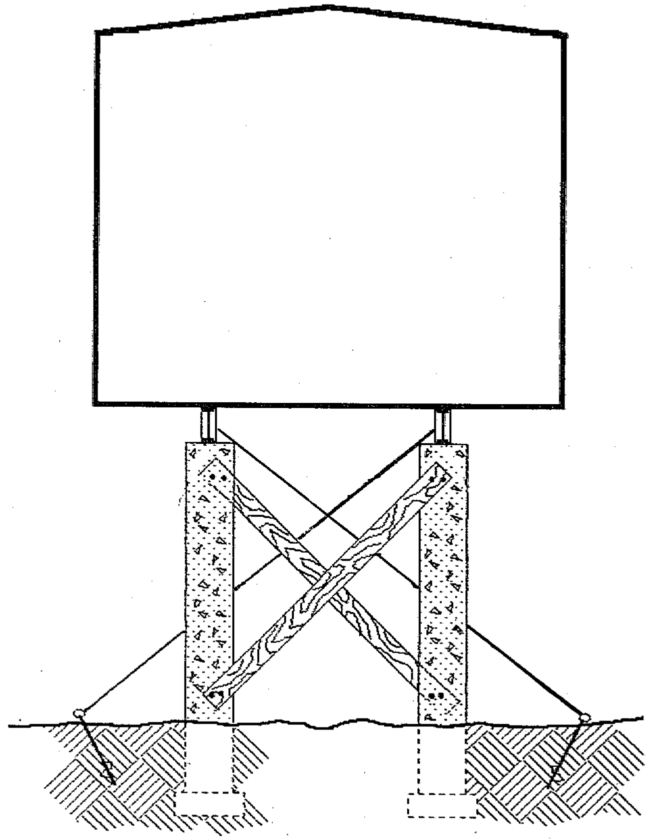


Figure 4.32 Typical Ground Anchor Detail

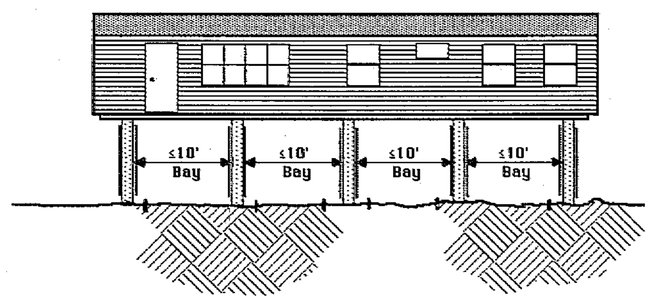


Figure 4.33 Longitudinal Spacing of Ground Anchors

To provide additional stability and resistance to anticipated loads, all pier designs must have the bottom of the footing at least 30 inches below grade or to the frostline, whichever is greater.

The bearing capacity of the soil must be greater than the maximum vertical load through the piers. Based on the information in Table 4.10, the maximum vertical load is determined and must be added to the weight of each pier and footing. In calculating the vertical load, a weight of 150 pounds per foot of pier should be used and 400 pounds for each footing. Hence, a ten foot pier and footing would weight 1900 pounds. If the bearing capacity of the soil is exceeded, the footing area must be increased or additional piers added.

Further support and resistance to lateral loads is provided by two inch by six inch pressure treated wood cross bracing. The pier design, anchorage, cross bracing, and footing details needed to elevate a manufactured home are then combined to form the elevated foundation as shown in Figure 4.34.

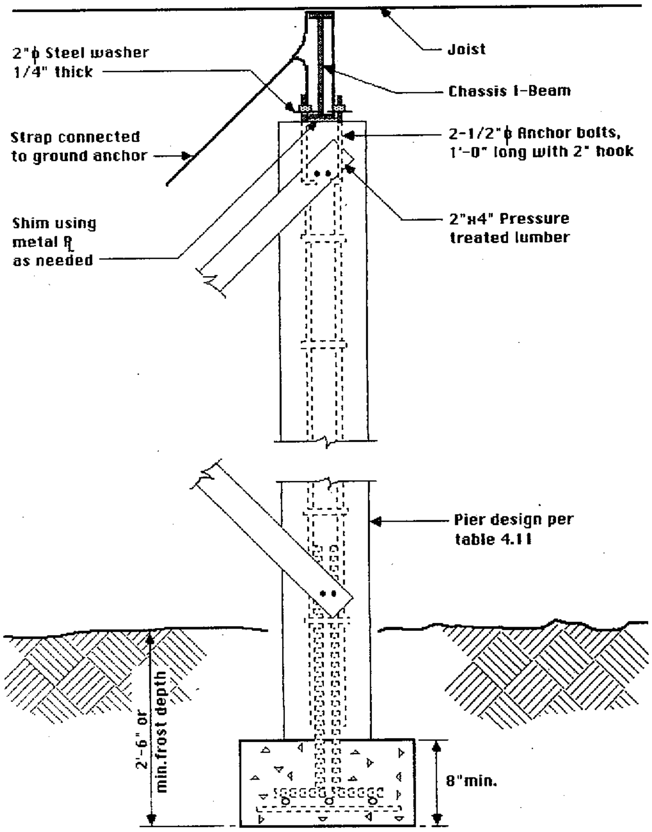


Figure 4.34 Elevated Pier Design

Where floodwaters are anticipated to rise above the floor of the manufactured home, then additional ground anchoring must be provided to secure the manufactured home against vertical and lateral flood forces. **Anchoring by connection of the manufactured home to the piers will not resist flotation.** Note, as previously discussed and shown in Appendix E, additional ground anchoring to resist flood loads will be effective in only limited cases. Additional elevation by increasing pier height will eliminate this concern.

Posts and Piles—The vertical members (posts or piles) of an elevated foundation must support manufactured home loads which are subsequently resisted by end bearing on undisturbed soil or concrete footings as shown in Figure 4.35.

As previously discussed, the first consideration in designing an elevated foundation is the capability for the soil to support the anticipated loading imposed by the vertical support members. Without such consideration, the entire foundation can

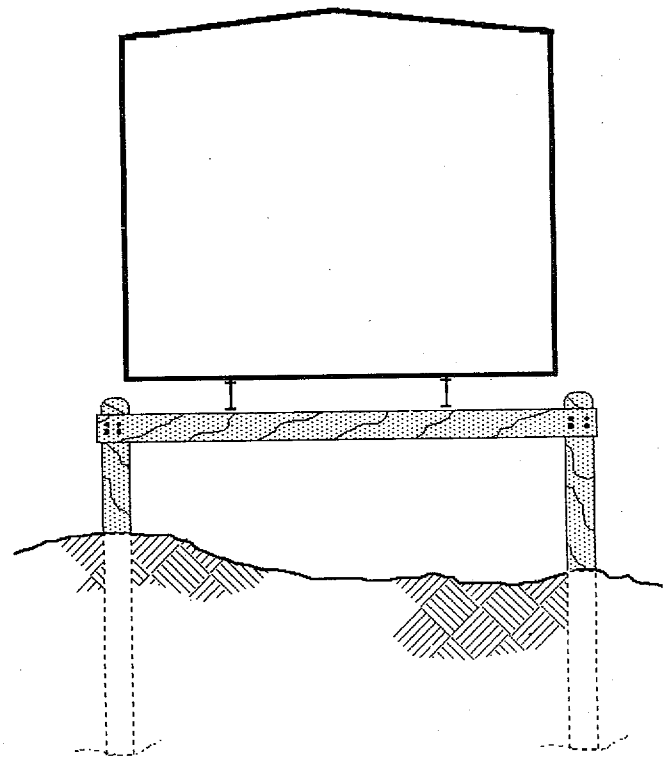


Figure 4.35 Posts and Piles

settle or sink into the ground. Prior to selecting the vertical members (posts or piles), the bearing capacity of the soil on the manufactured home site must be determined. This value will become the maximum allowable design load for selection of the vertical members.

Pile foundations, as opposed to other vertical wood members, rely on a combination of end bearing and side friction caused by the pile driving process to resist both vertical and horizontal loads. The frictional capability of piles is heavily dependent on local soil conditions and driving methods. For this reason, a full scale pile load test at the manufactured home site is the most reliable method of determining pile capacity. The results of such a test can be used in lieu of the vertical member capacity values presented in Tables 4.13. to 4.16. If pile capacity tests are not conducted, then the information on vertical member capacity in Tables 4.13 to 4.16 must be used.

Tables 4.13 to 4.16 provide data on square and round vertical wood member capacity as a function of total vertical member length, diameter, wind load, and manufactured home width. Total vertical member length as used in these tables includes height above grade, depth of embedment, and scour considerations. Note that for a double section manufactured home, these values are applicable, and two side-by-side foundation systems must be constructed.

The information in these tables can be used to determine the vertical member size necessary to support a given manufactured home installation. Based on the wind and roof live loads, manufactured home width, and total member length **including any scour considerations**, the vertical member capacity is provided and the size of vertical member chosen.

Based on the support spacing, wind and roof live loads, manufactured home width, and chassis I-beam spacing, a vertical member load is chosen from Table 4.10. Based on the length of the ver-

Table 4.13

VERTICAL MEMBER CAPACITY (pounds per member)[1]

Wind Design = 15 psf
Home Width = 12 feet

Length[2] (ft.)	Vertical Member Diameter (in.)									
	Square[3]					Round[4]				
	4	6	8	10	12	4	6	8	10	12
1	2250	7477	16576	29925	47750	2065	6161	13084	23144	36548
2	1319	4660	10844	20364	33572	1189	3731	8262	15142	24645
3	933	3384	8058	15433	25886	834	2675	6037	11251	18590
4	720	2657	6411	12425	21064	642	2085	4756	8951	14924
5	585	2187	5323	10398	17756	522	1708	3924	7432	12465
6	492	1855	4550	8939	15346	439	1445	3339	6354	10702
7	423	1611	3969	7840	13512	378	1253	2906	5549	9376
8	368	1422	3521	6981	12069	331	1105	2570	4924	8342
9	324	1272	3162	6284	10905	293	988	2304	4427	7514
10	289	1148	2869	5717	9946	262	892	2088	4016	6835
11	260	1045	2624	5242	9130	237	813	1908	3677	6269
12	236	956	2416	4840	8444	216	745	1756	3390	5783
13	216	877	2238	4493	7853	198	687	1626	3144	5370
14	199	809	2082	4191	7337	183	635	1513	2931	5012
15	-	751	1944	3926	6885	169	591	1414	2744	4698
16	-	700	1820	3691	6483	158	551	1326	2579	4420
17	-	655	1706	3481	6124	-	517	1247	2432	4173
18	-	615	1605	3291	5802	-	486	1174	2300	3952
19	-	579	1513	3119	5510	-	458	1109	2181	3752
20	-	547	1431	2960	5245	-	434	1050	2072	3570

[1]Maximum capacity limited to bearing capacity of soil; i.e., if soil capacity is 4000 psf, that becomes the limiting factor in determining configuration or end bearing area must be increased.

[2]Length is determined as total height above and below grade with depth of embedment greater than or equal to the height above grade but not less than six feet plus the addition of scour depth as previously discussed.

[3]Rough dimensions. Nominal dimension will be 1/2 inch less per side on square posts.

[4]Rough dimension as diameter of round member.

tical member, including anticipated scour depth, a vertical member size is chosen which is capable of supporting that load consistent with the soil bearing capacity of the site.

Consider a 14 foot by 66 foot manufactured home having a 99-inch chassis I-beam spacing with a desired elevation of five feet above grade and a recommended support spacing of eight feet located in a 25 psf wind load and 20 psf roof live load zone, where no scour is anticipated and soil bearing capacity is 3,000 psf as shown in Figure 4.36.

Table 4.14

VERTICAL MEMBER CAPACITY (pounds per member)[1]

Wind Design = 15 psf
Home Width = 14 feet

Length[2] (ft.)	Vertical Member Diameter (in.)									
	Square[3]					Round[4]				
	4	6	8	10	12	4	6	8	10	12
1	2454	8049	17674	31674	50245	2261	6672	14048	24678	38749
2	1461	5113	11804	22019	36093	1321	4112	9046	16482	26690
3	1040	3746	8861	16875	28161	933	2972	6671	12373	20355
4	805	2956	7093	13679	23087	720	2327	5284	9904	16450
5	656	2441	5913	11501	19562	586	1912	4374	8256	13803
6	552	2074	5069	9921	16971	493	1620	3732	7078	11889
7	475	1804	4431	8723	14986	425	1406	3254	6195	10441
8	413	1595	3936	7783	13417	373	1241	2881	5507	9308
9	363	1427	3540	7017	12145	330	1110	2585	4957	8397
10	323	1289	3215	6391	11094	295	1004	2345	4501	7648
11	291	1173	2943	5867	10196	266	915	2144	4125	7022
12	264	1073	2711	5421	9439	242	839	1974	3806	6482
13	241	984	2512	5036	8786	222	773	1829	3532	6024
14	222	907	2337	4701	8215	205	715	1702	3294	5625
15	-	841	2182	4405	7713	190	664	1591	3085	5276
16	-	783	2043	4143	7267	177	619	1492	2901	4966
17	-	732	1915	3908	6868	-	580	1403	2736	4691
18	-	687	1800	3695	6509	-	545	1321	2588	4443
19	-	647	1696	3502	6184	-	514	1247	2454	4219
20	-	611	1604	3323	5887	-	486	1180	2331	4016

[1]Maximum capacity limited to bearing capacity of soil; i.e., if soil capacity is 4000 psf, that becomes the limiting factor in determining configuration or end bearing area must be increased.

[2]Length is determined as total height above and below grade with depth of embedment greater than or equal to the height above grade but not less than six feet plus the addition of scour depth as previously discussed.

[3]Rough dimensions. Nominal dimension will be 1/2 inch less per side on square posts.

[4]Rough dimension as diameter of round member.

The vertical member load, based on wind load, roof live load, home width, dead and floor live loads, and the longitudinal spacing of vertical supports, is derived from Table 4.10. For the manufactured home installation in this example, the load is 4,640 pounds per vertical member as shown in Figure 4.37.

Referring to Table 4.16 on vertical member capacity, it is found a 12-inch diameter round or square post is acceptable based on the vertical member capacity and length of 11 feet (five feet above grade plus six feet embedment) as shown in Figure 4.38.

Because the vertical member load in psf is greater than the soil bearing capacity of 3,000 psf, a bearing pad must be provided for each post. The minimum area is as follows:

$$\frac{4640 \text{ lb.}}{3000 \text{ psf}} = 1.55 \text{ sq. ft.}$$

Note that in this example, if a 12 inch square member were chosen a vertical member length

Table 4.15

VERTICAL MEMBER CAPACITY (pounds per member)[1]

Wind Design = 25 psf
Home Width = 12 feet

Length[2] (ft.)	Vertical Member Diameter (in.)									
	Square[3]					Round[4]				
	4	6	8	10	12	4	6	8	10	12
1	1657	5722	13071	24168	39323	1503	4630	10095	18250	29354
2	929	3371	8027	15378	25798	831	2664	6013	11209	18523
3	645	2389	5792	11277	19196	574	1870	4282	8088	13530
4	493	1850	4531	8902	15284	438	1440	3325	6326	10658
5	399	1510	3720	7354	12697	354	1171	2717	5195	8791
6	335	1273	3156	6264	10859	297	986	2297	4407	7481
7	287	1101	2738	5456	9485	255	852	1990	3826	6511
8	250	969	2418	4832	8421	223	749	1754	3381	5763
9	221	865	2165	4333	7571	198	668	1568	3028	5170
10	198	780	1959	3929	6876	178	603	1418	2740	4687
11	178	710	1788	3593	6294	161	549	1293	2503	4287
12	162	650	1645	3309	5804	147	503	1189	2304	3946
13	149	597	1521	3067	5385	135	464	1100	2133	3658
14	137	552	1414	2857	5022	125	430	1022	1986	3408
15	-	513	1320	2673	4704	116	400	955	1858	3190
16	-	479	1237	2511	4424	108	374	895	1745	2998
17	-	449	1161	2366	4174	-	351	842	1644	2828
18	-	423	1093	2236	3950	-	330	794	1554	2675
19	-	399	1033	2119	3749	-	312	751	1473	2538
20	-	377	978	2012	3566	-	296	712	1399	2414

[1]Maximum capacity limited to bearing capacity of soil; i.e., if soil capacity is 4000 psf, that becomes the limiting factor in determining configuration or end bearing area must be increased.

[2]Length is determined as total height above and below grade with depth of embedment greater than or equal to the height above grade but not less than six feet plus the addition of scour depth as previously discussed.

[3]Rough dimensions. Nominal dimension will be 1/2 inch less per side on square posts.

[4]Rough dimension as diameter of round member.

of 16 feet (eight feet above grade and eight embedment) could be used because its capacity at 4906 pounds is greater than the vertical member load of 4640 pounds. If a six foot spacing were used, in lieu of an eight foot spacing, the load per post in this case is reduced to 3,480 pounds and a 10 inch square post could be used with a subsequent reduction in bearing pad area.

By changing the vertical member spacing, determining the applicable load and comparing that load with different vertical member capacities, as shown in this example, a number of elevated design strategies can be determined for a particular site.

As previously discussed, state and local regulations for manufactured home installations may impose a height limitation on elevated foundations unless they are designed by a registered professional engineer. **Where elevations over state or local height limitations are anticipated, the materials in this chapter can be used as general guidance but should not be used in lieu of obtaining an elevated foundation design by a registered professional engineer.**

Table 4.16

VERTICAL MEMBER CAPACITY (pounds per member)[1]

Wind Design = 25 psf
Home Width = 14 feet

Length[2] (ft.)	Vertical Member Diameter (in.)									
	Square[3]					Round[4]				
	4	6	8	10	12	4	6	8	10	12
1	1804	6170	13986	25698	41596	1641	5016	10863	19529	31259
2	1022	3686	8730	16640	27791	916	2923	6567	12189	20066
3	713	2628	6345	12303	20866	635	2062	4706	8859	14776
4	547	2024	4983	9759	16703	486	1593	3666	6958	11693
5	443	1670	4103	8087	13925	393	1298	3003	5729	9674
6	371	1410	3487	6904	11940	330	1094	2543	4869	8250
7	319	1221	3029	6023	10450	284	945	2205	4233	7191
8	278	1075	2678	5341	9290	249	832	1945	3744	6373
9	245	960	2399	4794	8362	220	743	1740	3357	5722
10	219	866	2172	4350	7603	197	670	1574	3039	5192
11	198	788	1984	3981	6963	178	610	1437	2778	4752
12	180	721	1825	3668	6426	163	560	1321	2557	4377
13	165	663	1689	3401	5966	150	516	1222	2369	4058
14	152	613	1570	3169	5566	138	478	1137	2206	3783
15	-	569	1466	2966	5216	128	444	1062	2064	3542
16	-	531	1373	2787	4906	120	415	996	1939	3330
17	-	498	1289	2627	4631	-	390	936	1827	3141
18	-	468	1213	2483	4383	-	367	883	1728	2973
19	-	441	1145	2352	4160	-	346	834	1638	2821
20	-	417	1084	2233	3958	-	328	791	1556	2683

[1]Maximum capacity limited to bearing capacity of soil; i.e., if soil capacity is 4000 psf, that becomes the limiting factor in determining configuration or end bearing area must be increased.

[2]Length is determined as total height above and below grade with depth of embedment greater than or equal to the height above grade but not less than six feet plus the addition of scour depth as previously discussed.

[3]Rough dimensions. Nominal dimension will be 1/2 inch less per side on square posts.

[4]Rough dimension as diameter of round member.

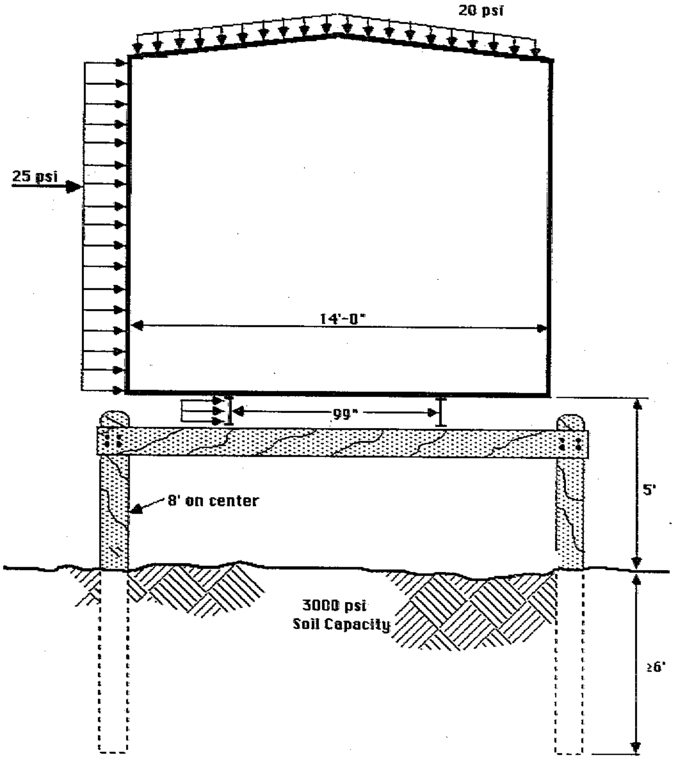


Figure 4.36 Manufactured Home Design Conditions

MAXIMUM VERTICAL MEMBER LOAD (pounds)

Longitudinal Spacing (ft.)	Manufactured Home Width (ft.)					
	12			14		
	Chassis I-Beam Spacing (in.)					
Wind Load = 15 psf Roof Live Load = 20 psf	75 1/2	82	99	75 1/2	82	99
5		2500			2900	
6		3000			3480	
7		3500			4060	
8		4000			4640	
9		4500			5220	
10		5000			5800	
Wind Load = 25 psf Roof Live Load = 20 psf						
5	2744	2669	2520	3044	2969	2900
6	3293	3203	3024	3653	3563	3480
7	3842	3737	3528	4262	4157	4060
8	4391	4271	4032	4871	4751	4640
9	4940	4805	4536	5480	5345	5220
10	5489	5339	5040	6089	5939	5800
Roof Live Load = 30 psf Wind Load = 15 or 25 psf						
5		2850			3300	
6		3420			3960	
7		3990			4620	
8		4560			5280	
9		5130			5940	
10		5700			6600	
Roof Live Load = 40 psf Wind Load = 15 or 25 psf						
5		3200			3700	
6		3840			4440	
7		4480			5180	
8		5120			5920	
9		5760			6660	
10		6400			7400	

Figure 4.37 Vertical Member Loads

VERTICAL MEMBER CAPACITY (pounds per member)[1]

Wind Design = 25 psf
Home Width = 14 feet

Length[2] (ft.)	Vertical Member Diameter (in.)									
	Square[3]					Round[4]				
	4	6	8	10	12	4	6	8	10	12
1	1804	6170	13986	25698	41596	1641	5016	10863	19529	31259
2	1022	3686	8730	16640	27791	916	2923	6567	12189	20066
3	713	2628	6345	12303	20866	635	2062	4706	8859	14776
4	547	2024	4983	9759	16703	486	1593	3666	6958	11693
5	443	1670	4103	8087	13925	393	1298	3003	5729	9674
6	371	1410	3487	6904	11940	330	1094	2543	4869	8250
7	319	1221	3029	6023	10450	284	945	2205	4233	7191
8	278	1075	2678	5341	9290	249	832	1945	3744	6373
9	245	960	2399	4794	8362	220	743	1740	3357	5722
10	219	866	2172	4350	7603	197	670	1574	3039	5192
11	198	788	1984	3981	6963	178	610	1437	2778	4752
12	180	721	1825	3668	6426	163	560	1321	2557	4377
13	165	663	1689	3401	5966	150	516	1222	2369	4058
14	152	613	1570	3169	5566	138	478	1137	2206	3783
15	-	569	1466	2966	5216	128	444	1062	2064	3542
16	-	531	1373	2787	4906	120	415	996	1939	3330
17	-	498	1289	2627	4631	-	390	936	1827	3141
18	-	468	1213	2483	4383	-	367	883	1728	2973
19	-	441	1145	2352	4160	-	346	834	1638	2821
20	-	417	1084	2233	3958	-	328	791	1556	2683

[1]Maximum capacity limited to bearing capacity of soil; i.e., if soil capacity is 4000 psf, that becomes the limiting factor in determining configuration or end bearing area must be increased.

[2]Length is determined as total height above and below grade with depth of embedment greater than or equal to the height above grade but not less than six feet plus the addition of scour depth as previously discussed.

[3]Rough dimensions. Nominal dimension will be 1/2 inch less per side on square posts.

[4]Rough dimension as diameter of round member.

Figure 4.38 Vertical Member Selection

In addition to wood posts or piles, steel pipe, steel structural sections, and concrete piles can be considered for elevated foundations. A presentation on the design methods for these materials is beyond the scope of this manual and assistance of a registered professional engineer is recommended if these materials are considered.

C. BRACING SUPPORT AND CONNECTIONS FOR ELEVATED FOUNDATIONS

Having determined the size, length, and spacing of the vertical members, the need for and design of horizontal supports, diagonal bracing, and connection details must be determined. In addition, where ground anchors are not used, the manufactured home must be securely connected to the elevated foundation. Figure 4.39 indicates where loading is applied to an elevated foundation system and what components of the elevated foundation must withstand anticipated loading.

Horizontal Support Beams

Where posts or piles are used to elevate the manufactured home, a structural member (horizontal support beam) must be connected between vertical members and run underneath the manufactured home to support the design loads as shown in Figure 4.40.

Horizontal cross members must be capable of supporting the dead load and floor live load of the manufactured home, as well as wind and roof live loads. At a five to 10 foot spacing of posts or piles the total weight including dead (20 psf), live (40

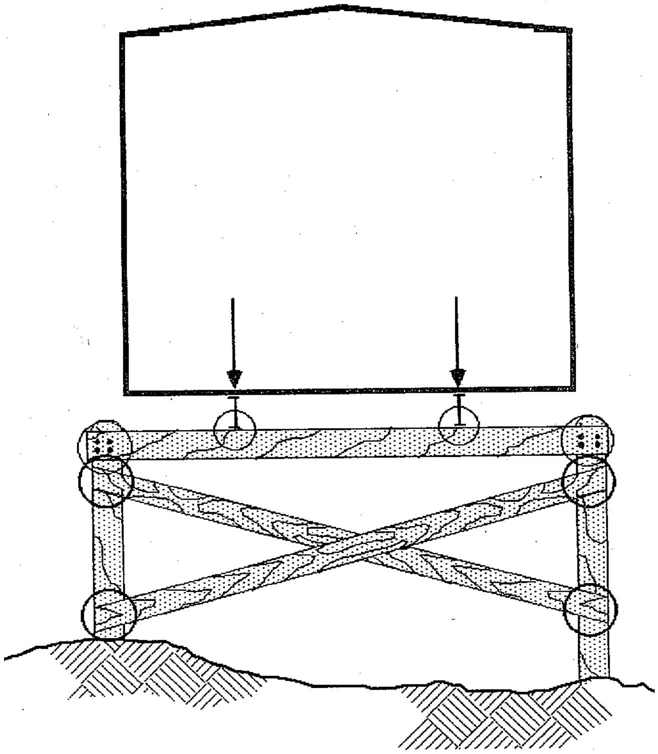


Figure 4.39 Elevated Foundation Loading

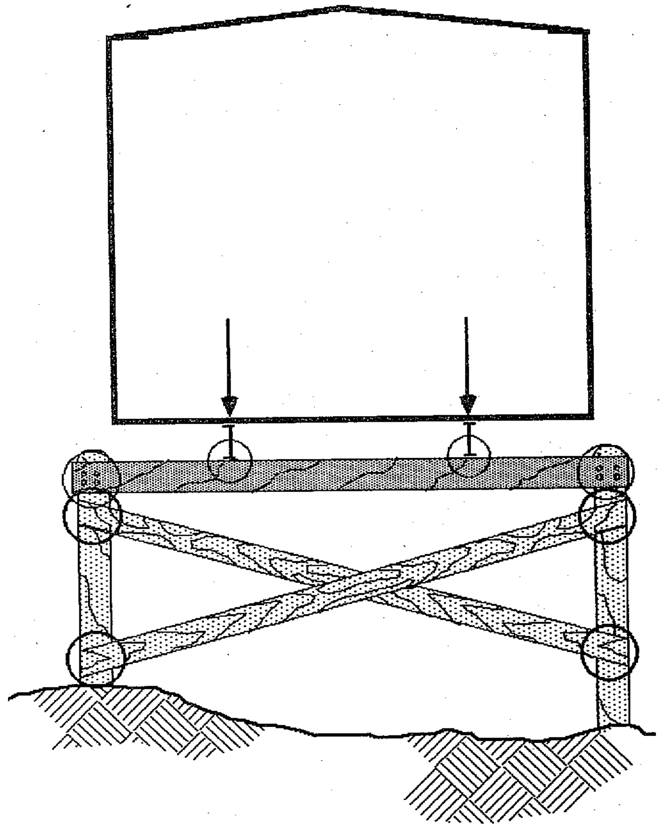


Figure 4.40 Horizontal Support Beam

psf), snow (20, 30, 40, psf) or wind (15, 25 psf) is shown in Tables 4.6 to 4.9.

Using these loads, the minimum horizontal beam sizes shown in Table 4.17 must be used to support the manufactured home and are based on sawn timber having an allowable bending stress (F_b) of 1250 psi, corrected for load duration, treatment, and service condition. Minimum beam sizes are determined as follows:

$$S_X = \frac{P \times e}{F'_b}$$

Where: S_X = minimum section modulus of beam (in^3)

P = load from chassis I-beam (lb)

e = distance from chassis I-beam to horizontal beam/vertical member connection (assumes 15 inches from side of manufactured home to the center line of the vertical member)

F'_b = allowable wood bending stress (psi) corrected = 1207.5 psi

For the purposes of the horizontal beam capacity and installation, the distance from the side of the manufactured home to the center line of the vertical member must not be more than 15 inches.

For instance, a 14 foot wide manufactured home located in a 20 psf roof live load and 25 psf wind load area having chassis I-beams 75-1/2 inches apart and longitudinal post spacings along the manufactured home of eight feet, would require four three-by 14-inch horizontal members between each post running under the manufactured home as shown in Table 4.17. Where other vertical member spacings or wood having a different bending stress is used, the equation previously shown can be used to calculate the minimum section modulus needed, and the required timber size determined.

Longitudinal beams placed above the horizontal support beams as shown in Figure 4.41 can provide additional support and will be needed if the manufacturer requires perimeter supports for the floor system. These transfer certain loads away from the center of the horizontal support beam.

Where longitudinal beams are used the vertical member capacity presented in Tables 4.13 to 4.16 must be reduced by five percent.

Cross Bracing

To improve the lateral stability of an elevated foundation system using vertical members bracing will be needed along the length of the elevated foundation between vertical members as shown in Figure 4.42. This becomes increasingly more important as the height above grade increases.

Tables 4.18 and 4.19 provide minimum recommended sawn timber sizes for cross bracing. The number of spans between vertical members (bays) needing cross bracing is shown along with the minimum sawn timber size. The required net area of the cross bracing is calculated using the allowable working stress in tension parallel to grain for the wood type used as follows:

$$A_n = \frac{P}{F_t}$$

Where:

A_n = Net area (sq. in.)

P = Axial load (lbs.)

F_t = Allowable working stress in tension parallel to grain (psi)

Based on a F_t of 531.3 psi (550 psi corrected for service condition, treatment and load duration factors), the minimum sawn timber sizes shown

Table 4.17

MINIMUM SAWN LUMBER HORIZONTAL BEAM

Vertical Member Spacing (ft.)	Manufactured Home Width (ft.)					
	12			14		
	Chassis I-Beam Spacing (in.)					
Wind Load = 15 Roof Live Load = 20 psf	75 1/2	82	99	75 1/2	82	99
5	2@ 3"x12"	2@ 3"x12"	2@ 2"x14"	2@ 3"x14"	2@ 3"x14"	2@ 3"x14"
6	4@ 2"x12"	2@ 3"x12"	2@ 2"x14"	4@ 2"x14"	4@ 2"x14"	2@ 3"x14"
7	2@ 3"x14"	2@ 3"x14"	2@ 3"x12"	4@ 3"x12"	4@ 3"x12"	4@ 2"x14"
8	4@ 2"X14"	2@ 3"X14"	4@ 2"X12"	4@ 3"x14"	4@ 3"x12"	4@ 2"x14"
9	4@ 2"x14"	4@ 2"x14"	2@ 3"x14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x12"
10	2@ 3"X16"	4@ 3"X14"	2@ 3"X14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x14"
Wind Load = 25 psf Roof Live Load = 20 psf						
5	2@ 3"x12"	2@ 3"x12"	2@ 3"x12"	4@ 2"x14"	2@ 3"x14"	4@ 2"x12"
6	4@ 2"x12"	2@ 3"x12"	4@ 2"x10"	4@ 2"x14"	2@ 3"x14"	4@ 2"x12"
7	4@ 2"x12"	2@ 3"x14"	4@ 2"x12"	4@ 3"x12"	4@ 3"x12"	4@ 2"x14"
8	4@ 2"X12"	2@ 3"X14"	4@ 2"X12"	4@ 3"x14"	4@ 3"x12"	4@ 2"x14"
9	4@ 3"x12"	4@ 2"x14"	2@ 3"x14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x12"
10	4@ 3"X12"	4@ 2"X14"	2@ 3"X14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x14"
Roof Live Load = 30 psf						
5	2@ 3"x14"	2@ 3"x12"	2@ 2"x14"	4@ 2"x14"	4@ 2"x14"	2@ 3"x14"
6	2@ 3"x14"	2@ 3"x14"	4@ 2"x12"	4@ 3"x12"	4@ 3"x12"	4@ 2"x14"
7	4@ 2"x14"	4@ 2"x14"	2@ 3"x14"	4@ 3"x14"	4@ 3"x12"	4@ 3"x12"
8	4@ 3"X12"	4@ 2"X14"	2@ 3"X14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x14"
9	4@ 3"x12"	4@ 3"x12"	4@ 2"x14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x14"
10	4@ 3"X14"	4@ 3"X14"	4@ 3"X12"	4@ 3"x16"	4@ 3"x16"	4@ 3"x14"
Roof Live Load = 40 psf						
5	2@ 3"x14"	2@ 3"x14"	2@ 3"x12"	4@ 3"x12"	4@ 2"x14"	2@ 3"x14"
6	4@ 2"x14"	2@ 3"x14"	4@ 2"x12"	4@ 3"x14"	4@ 3"x14"	2@ 3"x16"
7	4@ 3"x12	4@ 2"x14"	2@ 3"x14"	4@ 3"x14"	4@ 3"x14"	4@ 3"x12"
8	4@ 3"x12"	4@ 3"x12"	4@ 2"x14"	--	4@ 3"x14"	4@ 3"x14"
9	4@ 3"x14"	4@ 3"x12"	4@ 2"x14"	--	--	4@ 3"x14"
10	4@ 3"x14"	4@ 3"x14"	4@ 3"x12"	--	--	--

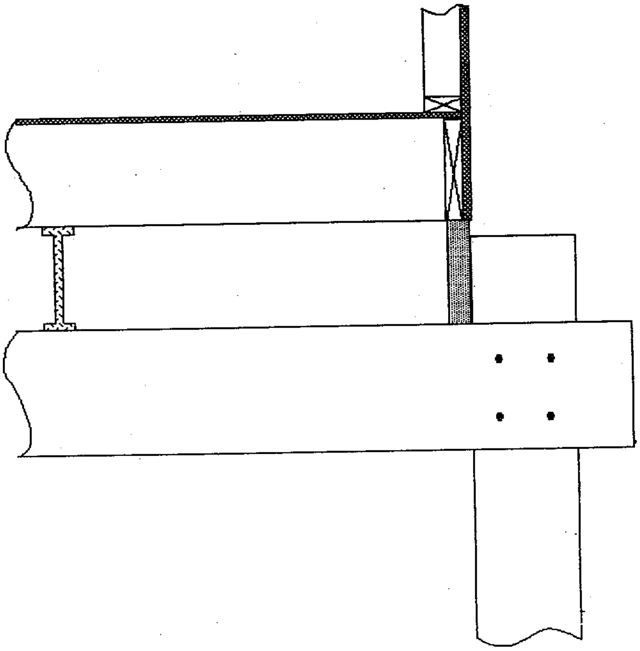


Figure 4.41 Longitudinal Support Beams

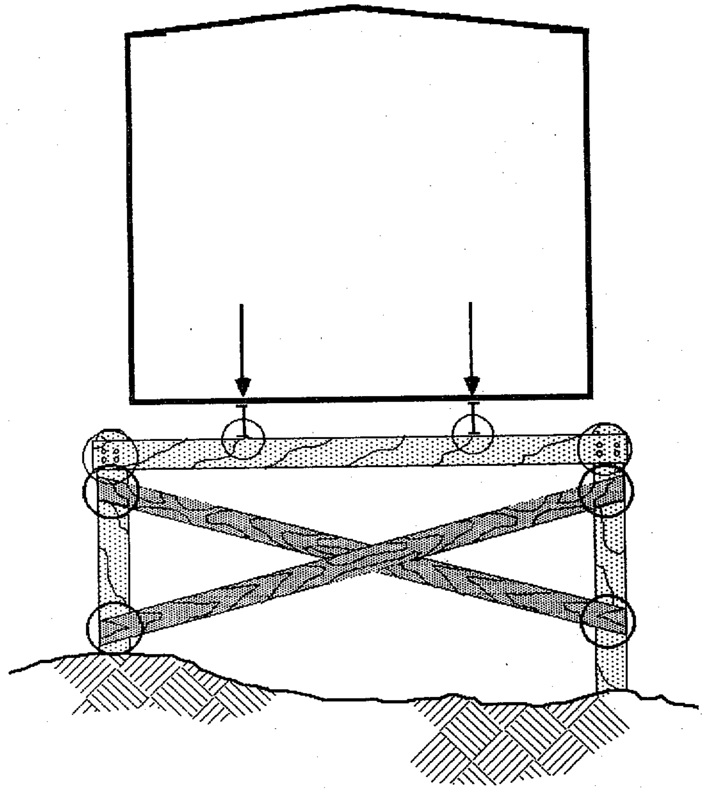


Figure 4.42 Cross Bracing

in Tables 4.18 and 4.19 are recommended. Diagonal bracing members should be placed between the posts under the home (across the width) at a minimum at each end and at the center span as shown in Figure 4.43.

For double section manufactured homes, both bays under the manufactured home must be braced using the width of one section of the manufactured home as appropriate.

For instance a 14 foot wide manufactured home in a 25 psf wind load area would, as shown in Figure 4.44, require two-by six-inch sawn timber diagonal bracing.

Table 4.18

MINIMUM SAWN TIMBER CROSS BRACING
(for 15 psf wind load)

Manufactured Home Length (ft.)	Height of Vertical Members Above Grade (ft.)							
	3	4	5	6	7	8	9	10
32	3 Braced Bays with 2"x 3" Members	3 Braced Bays with 2"x 3" Members	3 Braced Bays with 2"x 3" Members	3 Braced Bays with 2"x 3" Members	3 Braced Bays with 2"x 3" Members	3 Braced Bays with 2"x 3" Members		
40	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members		
48	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members
52	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 4" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members
56	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members	3 Braced Bays with 2"x 6" Members
60	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members
66	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members
72	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 4" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members	4 Braced Bays with 2"x 6" Members

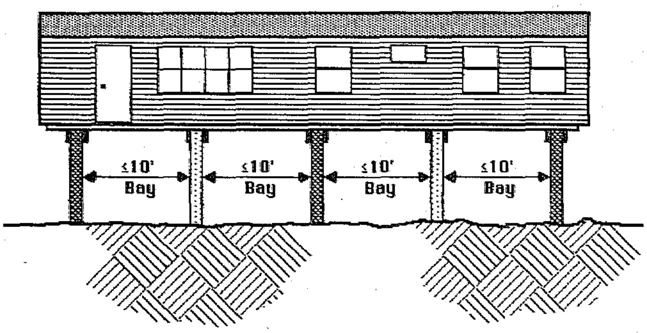


Figure 4.43 Cross Bracing Locations

A 28 foot wide manufactured home in the same area would, as shown in Figure 4.45, require use of two-by six-inch sawn timber diagonal bracing.

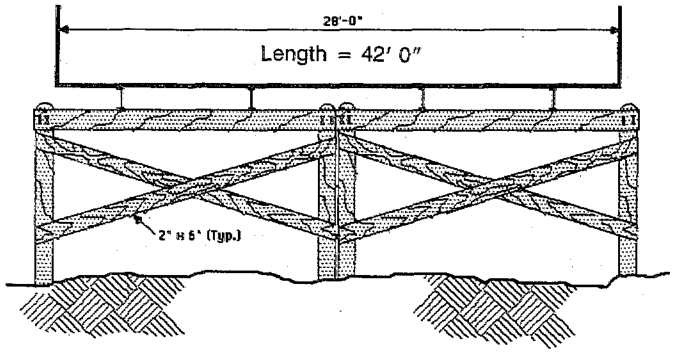


Figure 4.45 Cross Bracing—Double Section

Table 4.19

MINIMUM SAWN TIMBER CROSS BRACING
(for 25 psf wind load)

Manufactured Home Length (ft.)	Height of Vertical Member Above Grade (ft.)							
	3	4	5	6	7	8	9	10
32	3 Braced Bays with 2"x 4" Members							
40								
48	3 Braced Bays with 2"x 6" Members							
52								
56	3 Braced Bays with 2"x 8" Members							
60								
66		4 Braced Bays. with 2"x 6" Members						
72					4 Braced Bays with 2"x 8" Members			

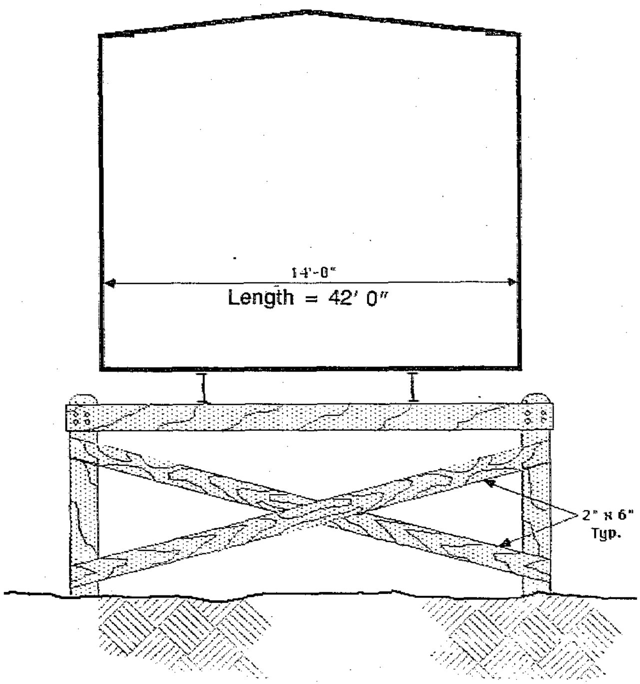


Figure 4.44 Cross Bracing—Single Section

End Bracing

In addition to cross bracing across the width of the manufactured home to counteract longitudinal wind loads, the end of the manufactured home will also experience wind loads. The end bays at each end of the manufactured home must, therefore, be braced as shown in Table 4.20, based on the same governing equation for wood cross bracing previously presented.

Table 4.20

MINIMUM SAWN TIMBER BRACING AT EACH END[1]

Wind Load = 25 psf Vertical Member Spacing (ft.)	Height of Vertical Member Above Grade (ft.)							
	3	4	5	6	7	8	9	10
5						Both End Bays at 2" X 6"		
6								
7								
8					Both End Bays at 2" X 4"			
9								
10		Both End Bays at 2" X 3"						

[1]Where the wind load = 15 psf, 2" by 3" sawn timber bracing at each end is acceptable at all vertical member spacings and height above grade values shown.

Connections

In the design of an elevated foundation system, there will be numerous connections which will differ depending upon the type of elevated foundation design chosen and the loads anticipated. Connection points are shown in Figure 4.46 and can be summarized as follows:

(1) Vertical member and horizontal support beams.

(2) Manufactured home I-beams to horizontal support beams.

(3) Diagonal bracing and vertical members.

(4) Longitudinal support beams and vertical members.

(5) End bracing and vertical members.

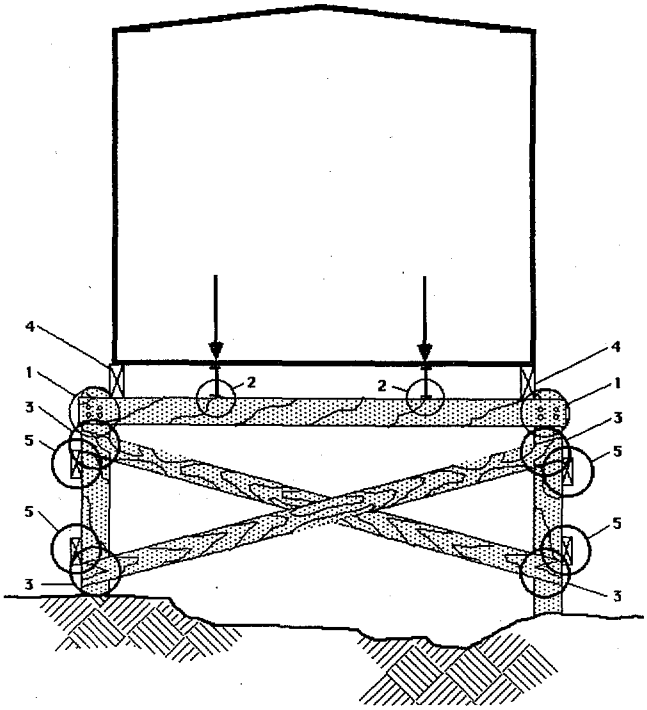


Figure 4.46 Elevated Foundation Connections

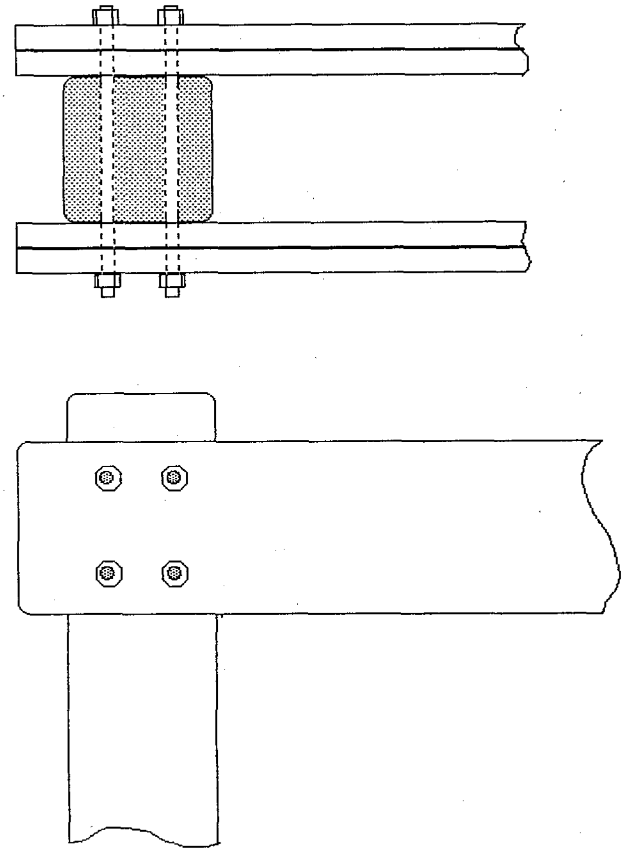


Figure 4.47 Bolts at Horizontal Beam and Vertical Member

Depending upon the design loads and type of elevated foundation and member sizes, the required connections will be subjected to different loads. These connections must withstand the loads so failure of the elevated foundation design does not occur.

Horizontal Beam

The total load on a horizontal beam is based on vertical support spacings, wind and roof live loads, as well as manufactured home width. The bolts connecting the horizontal beams to the vertical members, as shown in Figure 4.47 must be capable of carrying that load, thereby transmitting it to the vertical member.

Tables 4.21 and 4.22 provide the recommended number of bolts and their diameter for each horizontal beam to vertical member connection.

These values are based on design values for bolts loaded at both ends with loading perpendicular to grain for wood having a design value of 890-970 psi in wet service conditions. Note that all bolts must be of corrosion resistant metal and bolt holes drilled to one-sixteenth inch diameter greater than the required bolt diameter. To main-

Table 4.21

NUMBER AND DIAMETER OF BOLTS AT CONNECTION OF HORIZONTAL BEAMS TO SQUARE VERTICAL MEMBERS

Vertical Member Spacing (ft.)	Manufactured Home Width (ft.)	
	12	14
Wind Load = 15 or 25 psf Roof Live Load = 20 psf		
5	4 @ 5/8"	4 @ 5/8"
6	4 @ 5/8"	4 @ 5/8"
7	4 @ 5/8"	4 @ 7/8"
8	4 @ 5/8"	4 @ 7/8"
9	4 @ 3/4"	4 @ 7/8"
10	4 @ 7/8"	4 @ 7/8"
Roof Live Load = 30 psf		
5	4 @ 5/8"	4 @ 5/8"
6	4 @ 5/8"	4 @ 7/8"
7	4 @ 5/8"	4 @ 7/8"
8	4 @ 7/8"	4 @ 7/8"
9	4 @ 7/8"	4 @ 7/8"
10	4 @ 7/8"	4 @ 7/8"
Roof Live Load = 40 psf		
5	4 @ 5/8"	4 @ 7/8"
6	4 @ 5/8"	4 @ 7/8"
7	4 @ 7/8"	4 @ 7/8"
8	4 @ 7/8"	4 @ 7/8"
9	4 @ 7/8	4 @ 1"
10	4 @ 7/8"	4 @ 1"

Table 4.22

NUMBER AND DIAMETER OF BOLTS AT CONNECTION OF HORIZONTAL BEAMS TO ROUND VERTICAL MEMBERS

Vertical Member Spacing (ft.)	Manufactured Home Width (ft.) 12	14
Wind Load = 15 or 25 psf Roof Live Load = 20 psf		
5	3 @ 5/8"	3 @ 3/4"
6	3 @ 3/4"	3 @ 3/4"
7	3 @ 3/4"	3 @ 7/8"
8	3 @ 7/8"	3 @ 7/8"
9	3 @ 7/8"	3 @ 1"
10	3 @ 1"	3 @ 1"
Roof Live Load = 30 psf		
5	3 @ 5/8"	3 @ 3/4"
6	3 @ 3/4"	3 @ 7/8"
7	3 @ 7/8"	3 @ 7/8"
8	3 @ 7/8"	3 @ 1"
9	3 @ 1"	3 @ 1"
10	3 @ 1"	3 @ 1 1/4"
Roof Live Load = 40 psf		
5	3 @ 5/8"	3 @ 7/8"
6	3 @ 3/4"	3 @ 7/8"
7	3 @ 7/8"	3 @ 1"
8	3 @ 1"	3 @ 1"
9	3 @ 1"	3 @ 1 1/4"
10	3 @ 1 1/4"	3 @ 1 1/4"

tain the structural capacity of the vertical member, notching is not recommended.

Placement of the bolts at each connection is critical and from a structural standpoint must meet the following minimum spacing criteria.

Table 4.23 provides the minimum bolt spacing distances, as shown in Figure 4.48, as a function of the required bolt diameter for square vertical members.

Table 4.24 provides the minimum bolt spacing distances, as shown in Figure 4.49, as a function of the required bolt diameter for round vertical members.

Note that in some cases the horizontal beam or vertical member size may not facilitate the use of these minimum spacing criteria. In those cases, the vertical support spacing should be decreased and additional vertical members included, thereby distributing the loads over more connections and allowing the use of smaller diameter bolts.

Chassis I-Beams

The connection of the chassis I-beams to the horizontal support beams will be subject to uplift and lateral loads from wind and flood forces.

Table 4.23

MINIMUM BOLT SPACING DISTANCES
SQUARE VERTICAL MEMBERS

BOLT SIZE (in.) (d)	Dimension (in.) a (4d)	b (5d)	c (7d)	e (4d)	f (4d)	g (4d)	h (2 1/2d)	Minimum Vertical Member Dimension (2h + b)	Minimum Beam Depth (e + f + g)
5/8	2 1/2	3 1/8	4 3/8	2 1/2	2 1/2	2 1/2	1 9/16	6 1/4	7 1/2
3/4	3	3 3/4	5 1/4	3	3	3	1 7/8	7 1/2	9
7/8	3 1/2	4 3/8	6 1/8	3 1/2	3 1/2	3 1/2	2 3/16	8 3/4	10 1/2

Table 4.24

MINIMUM BOLT SPACING DISTANCES
ROUND VERTICAL MEMBERS

BOLT SIZE (in.) (d)	Dimension (inches) a (1 1/2d)	b (4d)	c (7d)	e (4d)	f (4d)	g (1 1/2d)	Minimum Vertical Member Dimension (2a)	Minimum Beam Depth (e + 2f + g)
5/8	1 5/8	2 1/2	4 3/8	2 1/2	2 1/2	15/16	1 7/8	8 7/16
3/4	1 1/8	3	5 1/4	3	3	1 1/8	2 1/4	10 1/8
7/8	1 5 16	3 1/2	6 1/8	3 1/2	3 1/2	1 5/16	2 5/8	11 13/16
1	1 1/2	4	7	4	4	1 1/2	3	13 1/2
1 1/4	1 7/8	5	8 3/4	5	5	1 7/8	3 3/4	16 7/8

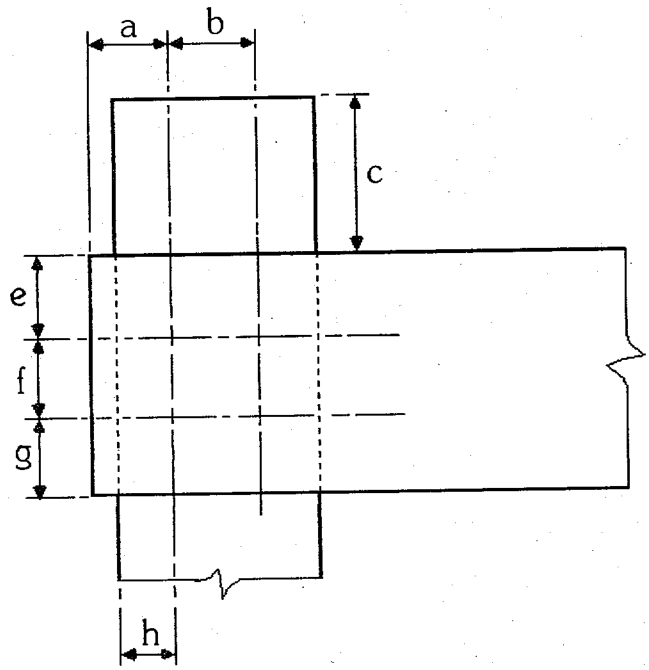


Figure 4.48 Minimum Bolt Spacing Distances for Square Vertical Members

Where no direct contact of the manufactured home with floodwaters is anticipated four lag screws should be used at each chassis I-beam/horizontal beam connection as shown in Table 4.25.

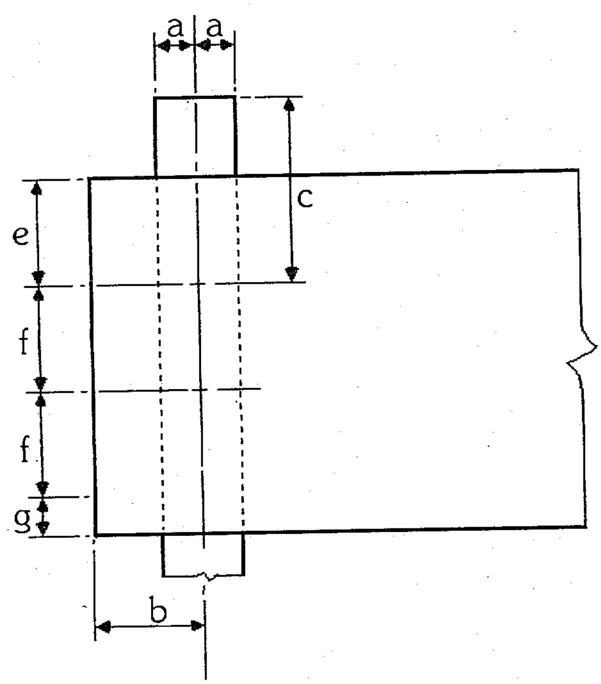


Figure 4.49 Minimum Bolt Spacing Distances for Round Vertical Members

Table 4.25

MINIMUM NOMINAL LAG SCREW SIZE (inches)

Support Spacing (ft.)	Wind Load	
	15 psf	25 psf
5	1/2 X 2	1/2 X 3
6	1/2 X 3	1/2 X 4
7	1/2 X 3	1/2 X 4
8	1/2 X 3	1/2 X 4
9	1/2 X 3	1/2 X 5
10	1/2 X 4	1/2 X 5

Figure 4.50 shows how these are to be applied at each chassis I-beam/horizontal beam connection. Other types of connections can be considered but must be designed to withstand both withdrawal and lateral loads imposed by uplift and lateral wind forces.

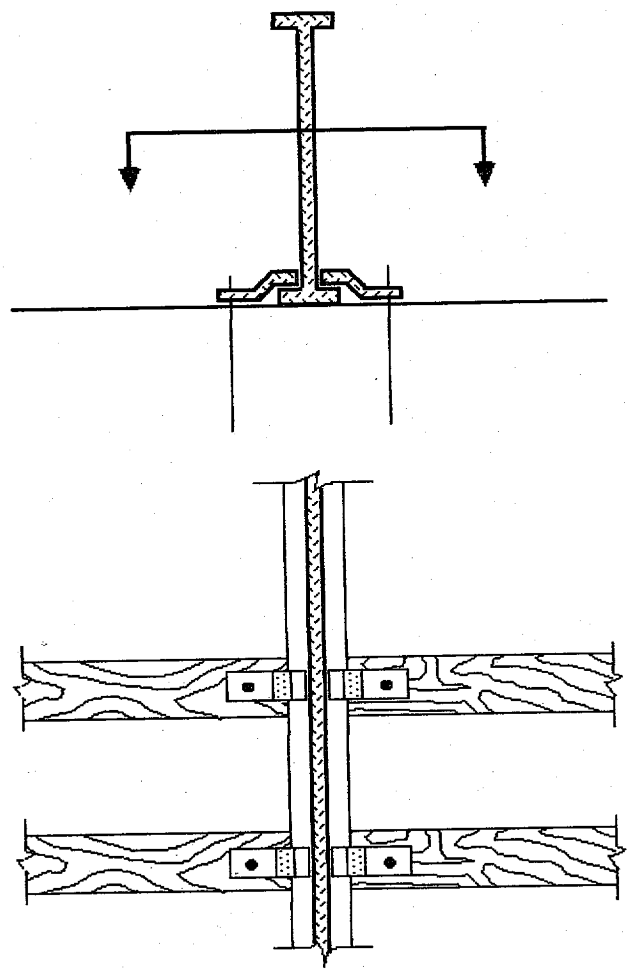


Figure 4.50 Chassis I-Beam Lag Screws

Where floodwaters will directly affect the manufactured home, the use of frame clips and lag screws **will not** be capable of withstanding the buoyancy forces created. In those cases, anchoring of the manufactured home with ground anchors must be considered or additional elevation considered to eliminate anticipated flood forces on the manufactured home.

Cross Bracing

Connections between wood cross bracing and vertical members as shown in Figure 4.51 must be designed to withstand loads imposed on the elevated foundation.

The following equation determines the minimum number of bolts required at each cross bracing to vertical member connection.

$$\text{Number of Bolts at Each Connection} = \frac{\text{Load}}{\text{Bolt Capacity from Table 4.26}}$$

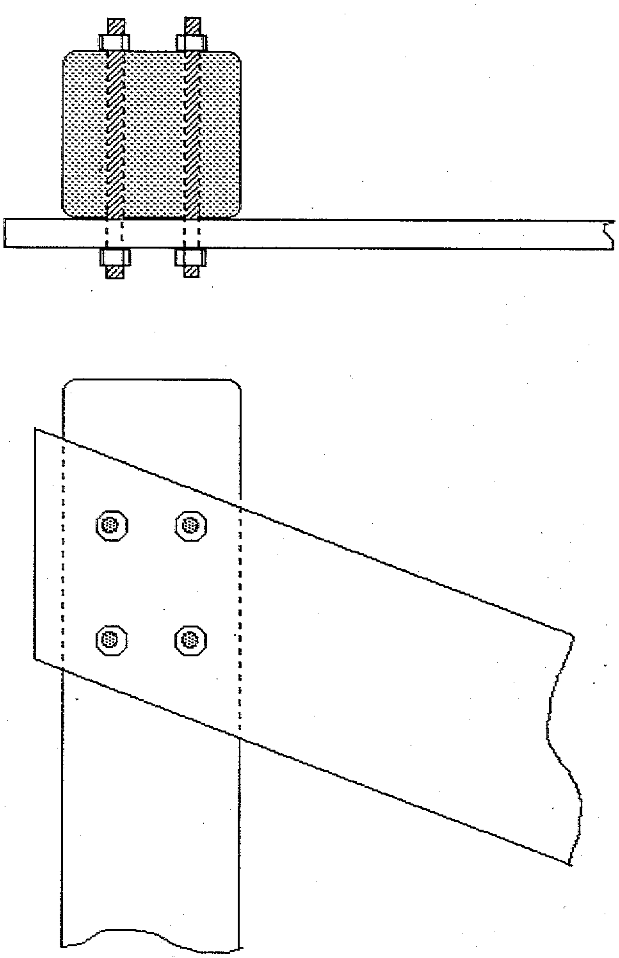


Figure 4.51 Cross Bracing Vertical Member Connection

Where: Load = load on each member (lb.) calculated as $(L \times F_d)/(2 \times \text{No. Bays})$

L = manufactured home length (ft.)

F_d = diagonal loading from Table 4.27 (lb./ft.)

No. Bays = Number of cross braced bays across the width of the manufactured home

Table 4.26 provides the capacity in pounds for various bolt diameters based on height of vertical members above grade and vertical member diameter.

Table 4.26

BOLT CAPACITY (pounds)

Height Above Grade (ft.)	Bolt Diameter (in.)	Vertical Member Diameter (in.)				
		4	6	8	10	12
3	1/2	568	-	-	-	-
	5/8	861	891	888	-	-
	3/4	1100	1273	1277	1273	-
4	1/2	554	-	-	-	-
	5/8	826	870	864	-	-
	3/4	1043	1234	1240	1232	-
5	1/2	537	-	-	-	-
	5/8	783	845	835	-	-
	3/4	977	1185	1195	1184	-
6	1/2	519	-	-	-	-
	5/8	739	817	803	-	-
	3/4	910	1134	1147	1131	-
	7/8	1056	1455	1546	1529	1517
7	5/8	697	788	771	-	-
	3/4	847	1083	1099	1080	-
	7/8	976	1367	1477	1457	1441
8	3/4	790	1034	1054	1031	-
	7/8	905	1287	1413	1389	1370
	1	1016	1525	1777	1802	1769
10	3/4	698	951	974	947	-
	7/8	791	1153	1300	1272	1249
	1	884	1340	1617	1647	1609

The anticipated diagonal loading due to lateral wind load per foot length of manufactured home is shown in Table 4.27 and is based on height above grade and wind load.

For example, consider a 60 foot manufactured home located in a 25 psf wind load zone with 8 inch vertical members six feet above grade and four braced vertical member bays. The load per diagonal member is calculated as follows:

$$\text{Load} = \frac{60 \text{ ft.} \times 265 \text{ lb./ft.}}{4 \times 2}$$

$$= 1{,}987.5 \text{ lb.}$$

Table 4.27

DIAGONAL LOADING
PER FOOT OF MANUFACTURED HOME
(pounds)

Height Above Grade (ft.)	Wind Load	
	15 psf	25 psf
3	149	248
4	151	252
5	155	257
6	159	265
7	164	273
8	170	283
10	183	305

Using Table 4.26 for the six foot above grade height and eight inch post diameter, it is found that 3/4 inch bolts have a capacity of 1,147 pounds each. The minimum number of bolts is calculated as follows:

$$\frac{1987.5 \text{ lb.}}{1147 \text{ lb./bolt}} = 1.73 \text{ or } 2$$

Therefore, using two three-quarter inch bolts at **each** diagonal wood bracing to vertical member connection will be acceptable.

End Bracing

For end bracing at the ends of the manufactured home, the size and number of bolts is determined in the same manner as presented for cross bracing. The load is determined using the manufactured home width as follows:

$$\text{Load} = \frac{\text{Width} \times F_d}{2}$$

For instance, if the 60 foot manufactured home in the previous example was 14 feet wide, the load per diagonal member is calculated as follows:

$$\text{Load} = \frac{14 \text{ ft.} \times 265 \text{ lb./ft.}}{2}$$

$$= 1855 \text{ lb.}$$

From Table 4.26 for the six foot above grade height and eight inch post diameter, a three-quarter inch diameter bolt has a capacity of 1,147 lb. The required number of bolts is calculated as follows:

$$\frac{1855 \text{ lb.}}{1147 \text{ lb./bolt}} = 1.6 \text{ or } 2.0 \text{ bolts per connection}$$

The diagrams shown in Figures 4.52 and 4.53 provide minimum dimensions for placement of bolts in the diagonal and vertical member connection. Bolt holes should be one-sixteenth inch larger than the diameter of the bolt and all connection hardware must be of corrosion resistant material.

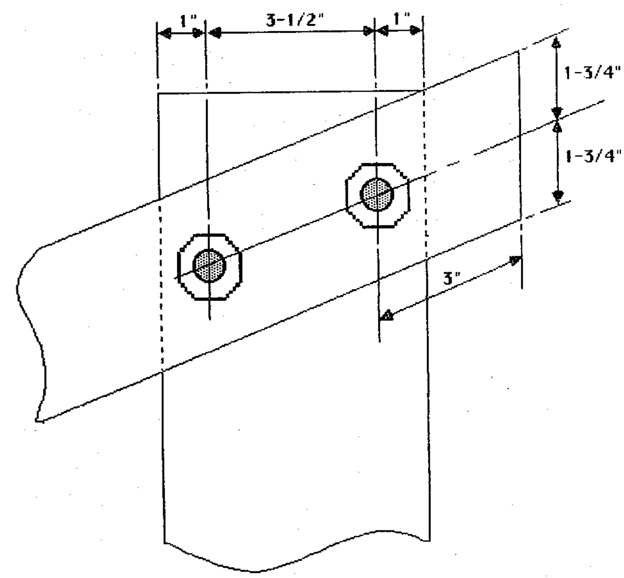


Figure 4.52 Two Bolt Connection

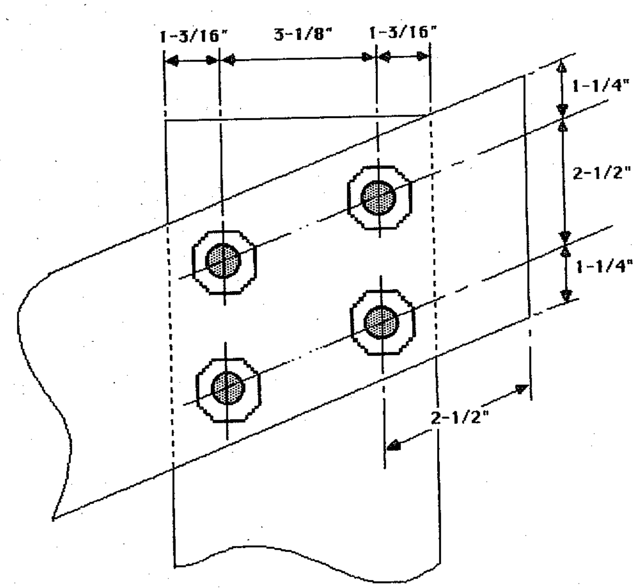


Figure 4.53 Four Bolt Connection

Longitudinal Support Beams

As previously discussed, any manufactured home requiring perimeter blocking must be supported by a longitudinal support beam. While the chassis I-beams of the manufactured home are connected to the horizontal support beams the longitudinal support beams may also be subjected to lateral wind loads. These loads are transferred to the connection of the longitudinal support beam to the post as shown in Figure 4.54.

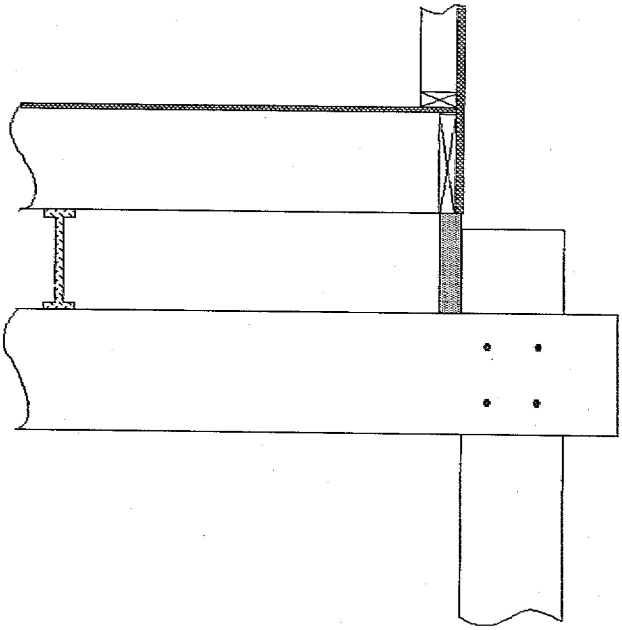


Figure 4.54 Longitudinal Support Beam Loading

At each longitudinal support beam and vertical member connection two lag screws at one half inch by five inches should be used as shown in Figure 4.55 to maintain the structural stability of this connection.

D. ADDITIONAL DESIGN CONSIDERATIONS

Having determined which siting and elevated foundation design will withstand given conditions, it is necessary to identify other construction and siting considerations which must be considered in implementing any elevated foundation design. These include such items as set-up, enclosures, utilities, location of mechanical equipment, and access/egress to and from the manufactured home.

Jacking

Jacking is the typical technique to elevate a manufactured home onto a foundation system. If the foundation must be placed in the ground, the foundation should be constructed first and the manufactured home elevated to its planned height. Equally spaced hydraulic jacks may be located under the steel frame adjacent to the planned foundation points, which are then moved under the home. A minimum of eight jacks should be used with additional jacks provided as follows:

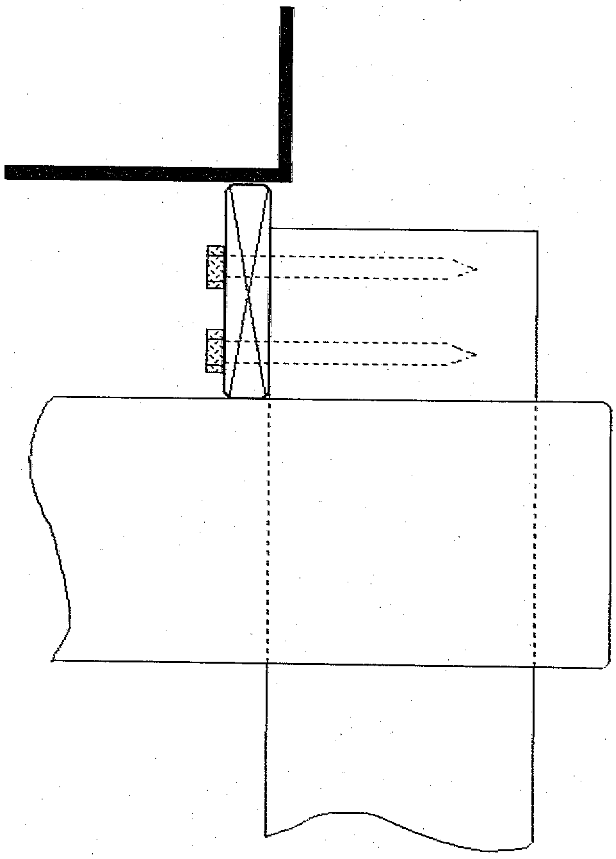


Figure 4.55 Longitudinal Support Beam Connection

$$\text{Jacks required} = \frac{W \times L \times 20 \text{ lb./ft.}^2}{C}$$

Where: W = Width of home (ft.)

L = Length of home (ft.)

C = Jack capacity (lb.)

Maximum jack extension is also a consideration. Where the elevation height exceeds the jack extension, a two step procedure consisting of jacking, blocking and jacking on top of elevated pads may be required. Temporary steel beam supports are then run perpendicular to and underneath the home's I-beams. They extend across the actual foundation site and are supported on both sides. The home is then moved across these beams lowered onto and secured to the elevated foundation.

Where jacking cannot be used to raise the manufactured home to the required elevation, the use of a crane should be considered.

Utility Service

Water, sewer, and gas services enter manufactured housing under the floor and originate from grade beneath the home. To connect the manufactured home to these services, utility pipes must extend from grade to the floor of the manufactured home. This location makes them extremely susceptible to flood inundation (leakage) and damage from floating debris. To minimize damage to these pipes, they should be placed in waterproof risers which are located adjacent to the elevated foundation members on the downstream side of the flood flow as shown in Figure 4.56.

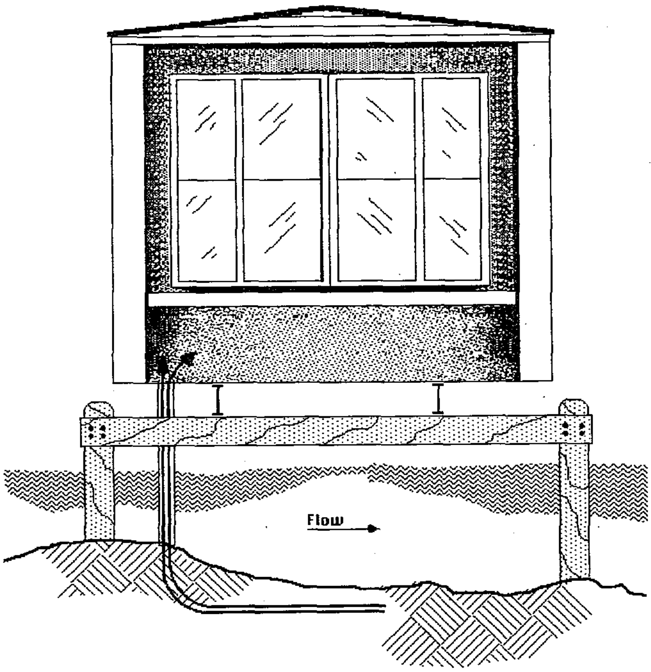


Figure 4.56 Utility Service Protection

Underground telephone and electric service should also be enclosed in a waterproof riser and protected as above for other utility service. If electrical and telephone service is supplied from overhead lines, the service connection to the manufactured home must be located above anticipated flooding as shown in Figure 4.57.

Applicable codes and regulations must also be followed when designing and installing utility service. These provisions may also require waterproofing of all connections, backflow preventors on water and sewer service, and the use of certain specific waterproof materials in and for these services.

Propane and fuel oil tanks used to supply energy for heating or other services should be

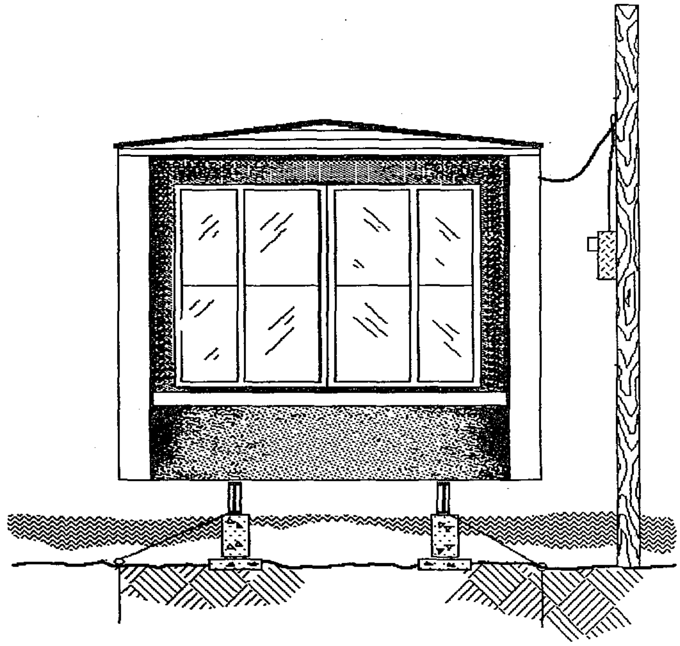


Figure 4.57 Overhead Utility Service

located in a waterproof enclosure or elevated above the anticipated flood level.

Methods to support these tanks above grade include separate elevated foundation systems or support from a platform built off the manufactured home foundation system. To minimize the potential for debris impact and damage, tanks and their supporting foundation should be located on the downstream side of the manufactured home. Figures 4.58 and 4.59 show suggested methods of elevating utility service tanks.

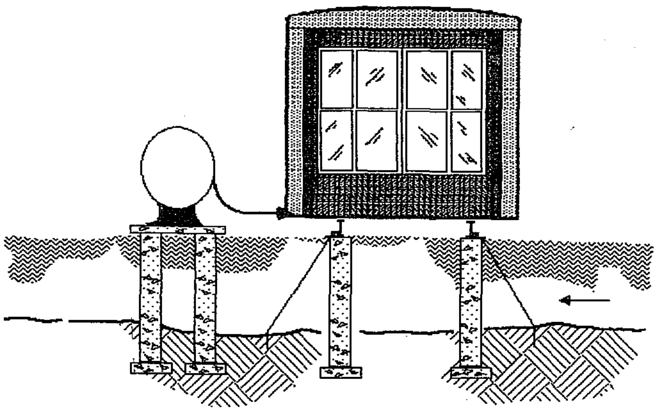


Figure 4.58 Separate Utility Service Tank Foundation

Mechanical Systems

Heating and air-conditioning equipment installed inside the manufactured home will generally be located directly under or on the floor. Elevation of the manufactured home above potential floods will, therefore, eliminate their being

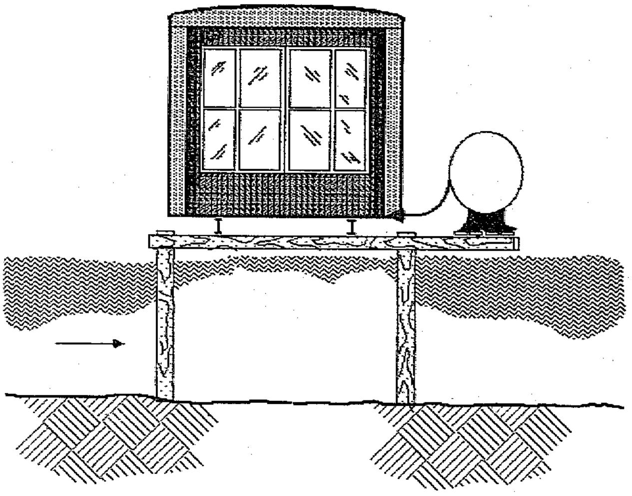


Figure 4.59 Connected Utility Service Tank Foundation

damaged. Where external components, such as an outdoor compressor/evaporator unit are installed, they must also be elevated above anticipated flooding. As with utility service tanks, these components are best located adjacent to the manufactured home on a separate platform supported by the elevated structure.

Access and Egress

A clear access and egress path to the manufactured home must be provided to allow evacuation and rescue efforts necessitated by a flood. Access and egress should be addressed during the evaluation of a potential site to ensure feasible alternates exist. Necessary considerations may also include bridges, walkways, and areas of safe refuge which allow safe evacuation during flooding.

Having considered Chapters I-IV of the manual a determination on the usability of a particular flood-prone site for manufactured housing should be possible. Where use of the land is feasible, at least one candidate design may be available for consideration. Such a site design could include site modifications, elevation of the manufactured home, anchoring or evacuation based upon an assessment of the flood forces and capacity of any candidate designs.

The design work sheet provided in Appendix F should be used in developing candidate designs in conformance with the manual.

Having developed a candidate design(s), the ability of the design(s) to survive anticipated flood occurrences should be assessed. At a minimum, the design would have to comply with the provisions of the National Flood Insurance Program (NFIP) which include certain tie-down and elevation requirements as previously discussed.

Based on an evaluation of the site, other measures may be warranted which will further reduce the potential for damage. These measures may, however, require additional costs over and above those necessary to comply with the minimum NFIP requirements. However, they will afford a greater probability of flood damage loss reduction which may offset or exceed the necessary costs to attain the additional protection.

Chapter V discusses the costs associated with improving the flood loss reduction potential for a manufactured home siting technique(s).

CHAPTER V

ECONOMICS

Costs associated with developing a site and elevating a manufactured home on the site are important factors in selecting an elevation strategy. These costs consist of those necessary to improve the site, erect the elevated foundation design developed pursuant to Chapter IV, and properly secure the manufactured home on that foundation.

This chapter presents a format and guidance for estimating the first costs associated with those site design options found acceptable from a technical standpoint. Cost ranges are provided with which a general estimate for a particular design can be developed. Due to the number of possible siting and flood situations, it is difficult to provide specific cost data on each particular design option. Moreover, the variance in labor rates, distance to the site, cost of materials, etc., further highlight the difficulty in developing and stating a firm fixed cost for each elevation technique.

In evaluating the economic aspects of an elevated manufactured home installation, the cost of a conventional installation must be recognized. This establishes a baseline cost with which additional improvement and elevation costs can be compared. The additional costs associated with improving the site and elevating the manufactured home (i.e., fill, elevation, anchoring, etc.) can then be considered in relation to the cost of a conventional installation.

Conventional Installations

As discussed in Chapter I, a conventional installation (without consideration of flooding) consists of piers on which the manufactured home rests and ground anchors to secure the manufactured home on top of the piers. The piers will generally be two feet in height and located under the manufactured home in accordance with the manufacturer's installation instructions. In addition, ground anchors will generally be installed every 10 feet along the length of the manufactured home.

The cost for a conventional installation two feet to the bottom of chassis I-beam will generally be as follows:

Cast-in place concrete piers	$100-$150/pier
Built-up unreinforced masonry piers	$ 50-$100/pier
Jacking and placement	$200-$300/section
Ground anchors and tie downs	$ 35-$75/anchor

Conventional installation costs, not including miscellaneous clearing, grading work, steps, utility connections, etc., are shown for various length single section manufactured homes in Table 5.1.

For various length double section manufactured homes, conventional installation costs are shown in Table 5.2.

As previously discussed, these cost ranges may not represent local conditions, labor and material rates, as well as conventional installations which may not utilize piers and ground anchors. Using these costs as a baseline, the following costs for fill and additional elevation through piers, posts, and piles can be placed in perspective. It is important to note that, in general, as the height above grade increases, the incremental cost for each additional foot of elevation decreases. This can be largely attributed to labor and other fixed costs which are essentially the same regardless of height. Therefore, additional elevation will provide a relatively low cost safety factor against unusually high flooding.

Earth Fill

Earth fill can be used to elevate a manufactured home in areas where flood velocity is not greater than 10 fps. Prices for any site work vary considerably due to the present condition of and need to clear the site, distance from sources of fill, quality of fill, and costs of the fill material. The cost for earth fill material will generally range from $2.00 to $4.00 per cubic yard, not including any additional site work required. In some cases, the total cost of elevating with fill may be as much as $10.00 to $12.00 per cubic yard. For instance, the Residential Cost Handbook by Marshall and Swift show costs from $2.43 to $3.78 for soft earth and $3.51 to $5.94 per cubic yard of fill for hard earth. If earth fill is considered for use in elevating a manufactured home local excavating and hauling contractors should be contacted for an accurate estimate.

Based on a cost of $2.00 to $4.00 per cubic yard of earth fill, the ranges in Table 5.3 are shown for various length single and double section manufactured homes.

Table 5.1

CONVENTIONAL INSTALLATION COSTS FOR SINGLE SECTION
(dollars)

	Manufactured Home Length (ft.)						
	48	52	56	60	66	72	76
Concrete Piers	1000-1500	1000-1500	1200-1800	1200-1800	1400-2100	1400-2100	1600-2400
Masonry Piers	500-1000	500-1000	600-1200	600-1200	700-1400	700-1400	800-1600
Ground Anchors	350- 750	350- 750	420- 900	420- 900	490-1050	490-1050	560-1200
Jacking	200- 300	200- 300	200- 300	200- 300	200- 300	200- 300	200- 300
TOTAL COST	1050-2550	1050-2550	1220-3000	1220-3000	1390-3450	1390-3450	1560-3900
Cost/Ft. Length	21.88-53.13	20.19-49.04	21.79-53.57	20.33-50.00	21.06-52.27	19.31-47.92	20.53-51.32

Table 5.2

CONVENTIONAL INSTALLATION COSTS FOR DOUBLE SECTION
(dollars)

	Manufactured Home Length (ft.)						
	32	40	48	52	56	60	66
Concrete Piers	1600-2400	1600-2400	2000-3000	2000-3000	2400-3600	2400-3600	2800-4200
Masonry Piers	800-1600	800-1600	1000-2000	1000-2000	1200-2400	1200-2400	1400-2800
Ground Anchors	280- 600	280- 600	350- 750	350- 750	420- 900	420- 900	490-1050
Jacking	400- 600	400- 600	400- 600	400- 600	400- 600	400- 600	400- 600
TOTAL COST	1480-3600	1480-3600	1750-4350	1750-4350	2020-5100	2020-5100	2290-5850
Cost/Ft. Length	46.25-112.50	37.00-90.00	36.46-90.63	33.65-83.65	36.07-91.07	33.67-85.00	34.70-88.64

Table 5.3

EARTH FILL COSTS[1]
(dollars)

Depth of Fill (ft.)	Manufactured Home Width (ft.)	Manufactured Home Length (ft.)								
		32	40	48	52	56	60	66	72	76
1	12	-	82- 164	94- 188	102- 204	108- 216	114- 228	124- 248	134- 268	140- 280
	14	-	88- 176	104- 208	110- 220	118- 236	124- 248	136- 272	146- 292	152- 304
	24	106- 212	126- 252	146- 292	156- 312	166- 332	176- 352	192- 384	-	-
	28	118- 236	140- 280	164- 328	174- 348	186- 372	198- 396	214- 428	-	-
2	12	-	184- 368	214- 428	228- 456	242- 484	256- 512	278- 556	299- 598	312- 624
	14	-	200- 400	232- 464	246- 492	262- 524	278- 556	300- 600	324- 648	340- 680
	24	234-468	278- 556	320- 640	342- 684	362- 724	384- 768	416- 832	-	-
	28	260-520	308- 616	356- 712	380- 760	402- 804	426- 852	462- 924	-	-
3	12	-	312- 624	358- 716	382- 764	404- 808	428- 856	462- 924	496- 992	520-1040
	14	-	336- 672	386- 772	410- 820	436- 872	460- 920	498- 996	536-1072	560-1120
	24	388- 776	456- 912	524-1048	558-1116	592-1184	624-1248	676-1352	726-1452	-
	28	430- 860	504-1008	578-1156	616-1232	654-1308	690-1380	746-1492	802-1604	-
4	12	-	465- 930	531-1062	564-1128	597-1194	631-1262	680-1360	730-1460	763-1526
	14	-	498- 996	569-1138	604-1208	640-1280	676-1352	729-1458	782-1564	818-1636
	24	569-1138	664-1328	759-1518	806-1612	853-1706	901-1802	972-1944	-	-
	28	626-1252	730-1460	843-1686	887-1774	939-1878	991-1982	1069-2138	-	-
5	12	-	644-1288	733-1466	778-1556	822-1644	866-1732	933-1866	1000-2000	1044-2088
	14	-	687-1374	782-1564	830-1660	877-1754	924-1848	996-1992	1067-2134	1114-2228
	24	778-1556	902-1804	1027-2054	1089-2178	1151-2302	1213-2426	1307-2614	-	-
	28	852-1704	988-1976	1124-2248	1193-2386	1261-2522	1329-2658	1431-2862	-	-

[1]The number of cubic yards of fill can be derived by dividing the first value in each range above by 2 since the cost for the first entry is based on $2.00/cu.yd.

The amount of earth fill needed can be entered in Part II of the Design Worksheet shown in Appendix F. The total cost can be estimated from Table 5.3 above or the cost per cubic yard can be secured from a local excavation and hauling contractor and applied to the amount of fill required.

Piers

As presented in Chapter IV, piers can be cast-in-place, built-up concrete masonry units, or brick. The cost of piers will vary due to local material and labor costs and will also be affected by constant fixed costs such as contractor equipment set-up. For instance, the Dodge Manual for Building Construction Pricing and Scheduling shows costs of $8.86 to $16.76 per linear foot for a cast-in-place concrete pier 12 inches square, while Marshall and Swift show $22.50 to $31.00 per linear foot. These costs do not cover footings, excavation, contractor set-up, and reinforcement costs.

For the purpose of estimating the cost of a pier foundation, the general cost ranges per pier shown in Table 5.4 can be used.

Based on the desired height above grade and number of piers needed to elevate the manufactured home, Part II of the Design Worksheet in Appendix F can be completed for the purposes of estimating the design costs. If piers are a design option, it is strongly suggested that a local contractor cost estimate be secured.

Assuming piers are installed at 10 foot intervals, the cost per foot of manufactured home, based on height above grade, is shown in Table 5.5.

Where additional ground anchors are used, a cost of $35.00 to $75.00 per ground anchor should be used.

Post and Piles

Depending upon the anticipated height, spacing, and anticipated loads, a post or pile design may be an option. The cost of these members will vary depending upon their length, diameter,and depth of embedment and will also be impacted by contractor fixed costs, such as equipment set-up. Of critical importance is the type of soil and ease with which these members can be secured in the ground. Marshall and Swift, for instance, show $8.20 installed for 10 inch and $10.15 for 12 inch creosoted wood piles plus fixed set-up costs. Based on estimates of $10.00 to $15.00 per foot of length, the general costs shown in Table 5.6 can be used.

Based on the desired height above grade and number of posts or piles needed to elevate the manufactured home, Part II of the Design Worksheet in Appendix F can be completed for the purpose of estimating the design costs. Not that a review of local costs will most likely indicate a small difference in pile costs regardless of diameter such that use of a larger diameter pile will provide additional support and may allow a reduction in the number of vertical members.

Assuming posts and piles are installed at 10 foot intervals, the cost per foot of manufactured home,

Table 5.4

PIER COSTS
(dollars)

	Height of Pier (ft.)							
	3	4	5	6	7	8	9	10
Cast-in-Place	150-210	200-280	250-350	300-420	350-490	400-560	450-630	500-700
Built-up Masonry	100-150	133-200	166-250	200-300	233-350	266-400	300-450	330-500

Table 5.5

COST PER FOOT OF MANUFACTURED HOME
(dollars)

	Height of Pier (ft.)							
	3	4	5	6	7	8	9	10
Single Section	20-42	27-56	33-70	40-84	47-98	53-112	60-126	66-140
Double Section	40-84	54-112	66-140	80-168	94-196	106-224	120-252	132-280

Table 5.6

POST AND PILE COSTS
(dollars)

Length of Member (ft.)										
10	11	12	13	14	15	16	17	18	19	20
100-150	110-165	120-180	130-195	140-210	150-225	160-240	170-255	180-270	190-285	200-300

based on height above grade and no consideration for scour, is shown in Table 5.7.

Table 5.7

COST PER FOOT OF MANUFACTURED HOME
(dollars)

	Height of Post/Pile Above Grade (ft.)						
	4	5	6	7	8	9	10
Single Section	20-30	22-33	24-36	28-42	32-48	36-54	40-60
Double Section	40-60	44-66	48-72	56-84	64-96	72-108	80-120

The design of a wood foundation also necessitates the use of horizontal beams, cross bracing, and other hardware such as bolts, clips, etc. In addition, labor costs to construct such an elevated foundation must be included. Because material and labor costs vary widely, as will the design of each wood foundation, it is very difficult to provide estimates for this aspect of an elevated wood foundation. Based on actual construction costs for elevated wood foundations, costs associated with these materials and their installation will be roughly equivalent to the cost of the installed vertical members. Hence, the total cost for a wood elevated foundation can be estimated by doubling the cost for the posts/piles previously presented.

Jacking

The placement of jacks and jacking of a manufactured home are based on the desired height above grade. Table 5.8 provides general estimates based on height above grade.

Miscellaneous

As discussed in Section D of Chapter IV, there will be other miscellaneous costs associated with elevating a manufactured home. These include utilities, equipment, access/egress, etc. Based on the height above grade, these costs should be approximately the same regardless of the method of elevation chosen. Subsequent to determining the desired height above grade, costs for these items should be developed with the help of a local contractor and included in Part II of the Design Worksheet in Appendix F. Note that even with a coventional installation, these costs will still be applicable. Essentially, the only cost increase can be attributed to materials and labor to extend or increase the height of the elevated manufactured home.

Summary of Total Costs

Based on the information presented in this chapter, it is possible to estimate the relative costs of various elevation strategies. As previously discussed, there are both fixed and variable costs associated with an installation. In addition, the cost of a conventional installation must be considered and subtracted from the elevated design cost to obtain the real cost of the elevated foundation design. Based on the information previously presented, Figures 5.1 and 5.2 have been prepared to provide a general overview and comparison of costs.

Figure 5.1 provides an estimated cost per foot length of manufactured home in comparison to height above grade for single section manufactured homes. Figure 5.2 provides the same information for double section manufactured homes.

Note, as previously discussed, costs for each particular installation will vary due to a number of design and site specific considerations. **It is, therefore, strongly recommended that cost estimates for each elevated design alternative be secured from as many manufactured home installation contractors as possible.**

Table 5.8

JACKING COSTS
(dollars)

	Height Above Grade (ft.)							
	3	4	5	6	7	8	9	10
Single Section	250-350	300-400	350-450	400-500	450-550	500-600	550-650	600-700
Double Section	500-700	600-800	700-900	800-1000	900-1100	1000-1200	1100-1300	1200-1400

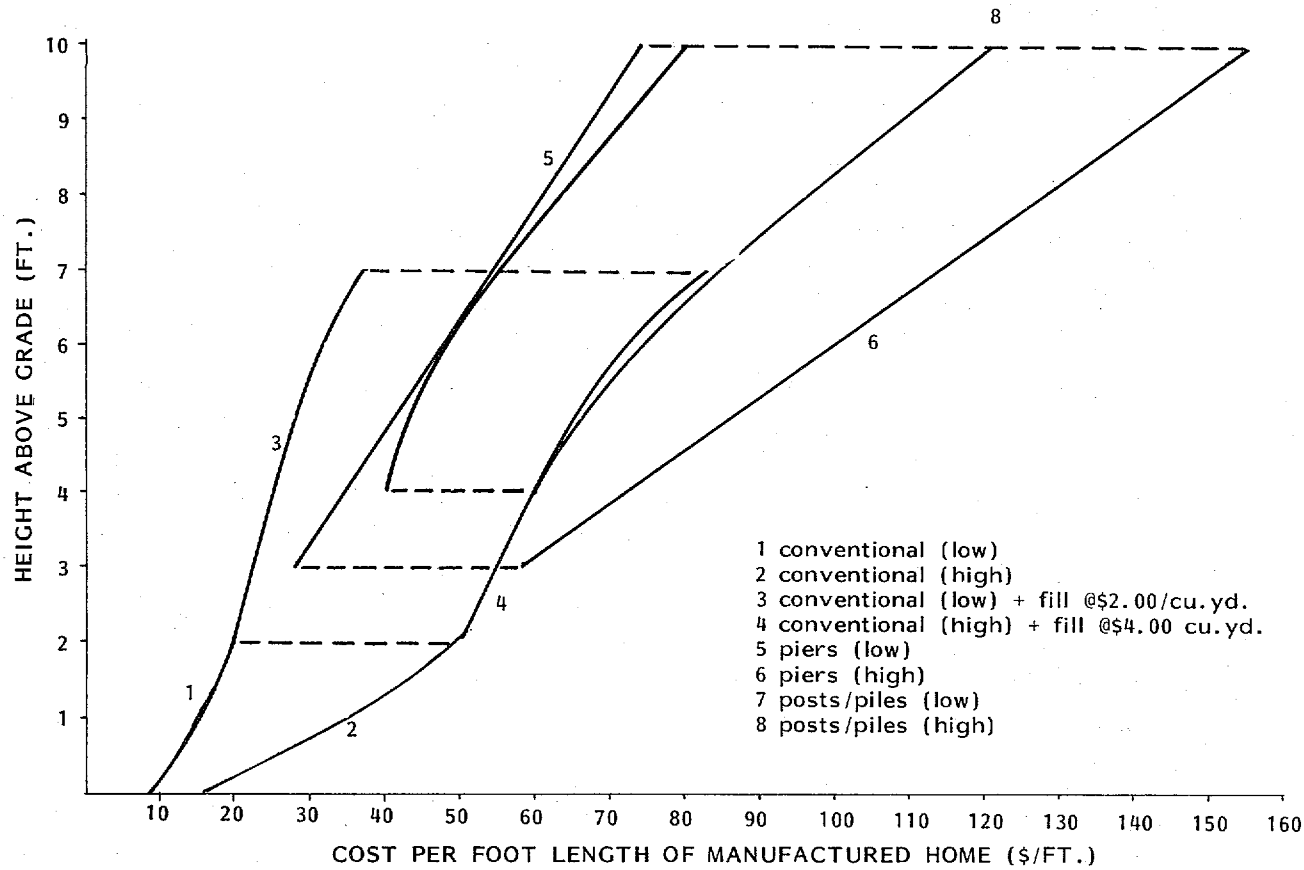


Figure 5.1 Single Section General Comparison of Material Costs

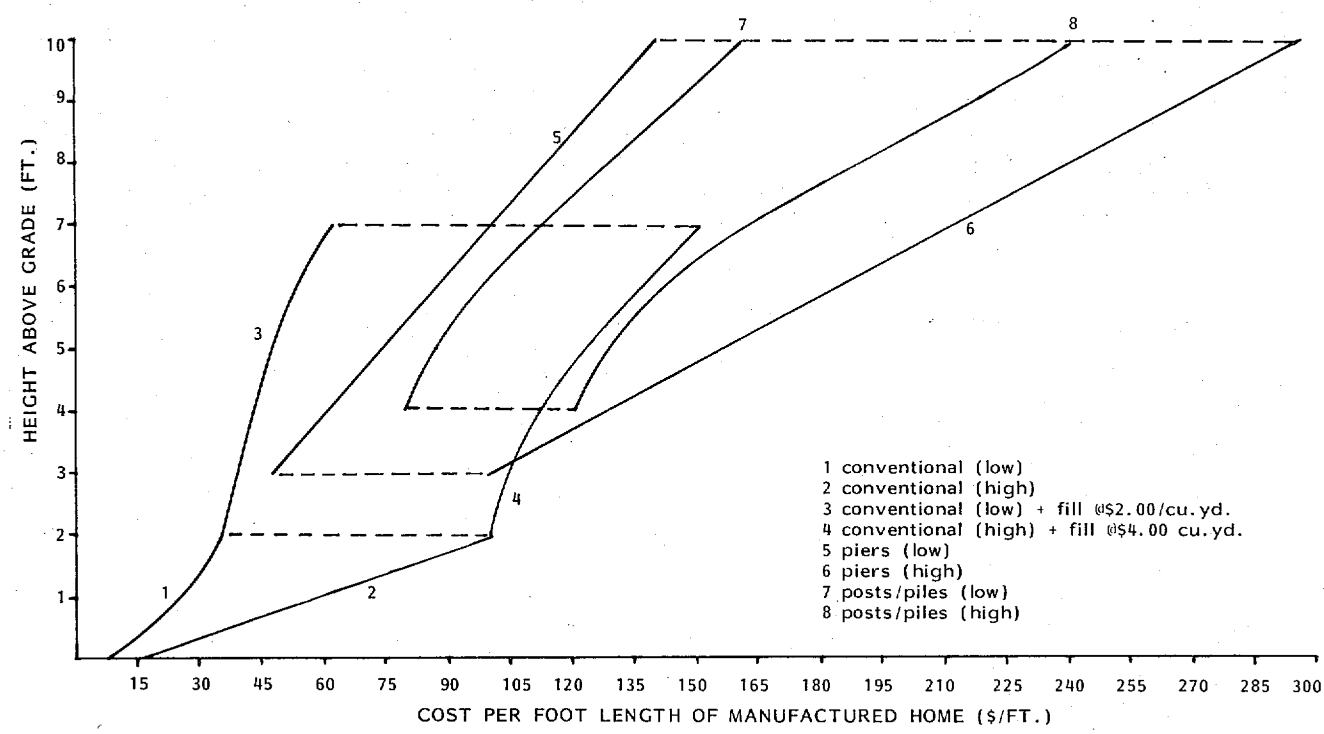


Figure 5.2 Double Section General Comparison of Material Costs

APPENDIX A

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Yokel, Felix Y., Riley M. Chung, Charles W. C. Yancey, National Bureau of Standards, "NBS Studies of Mobile Home Foundations," NBSIR 2238, 1981.

APPENDIX B

Federal and State Contacts

Federal Emergency Management Agency Regional National Flood Insurance Program Contacts

Region I
J. W. McCormack
POCH, Room 442
Boston, Massachusetts 02109
(617) 223-2616
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont

Region II
26 Federal Plaza
Room 1349
New York, New York 10278
(212) 264-4734
New Jersey, New York, Puerto Rico, and Virgin Islands

Region III
Liberty Square Building
Second Floor
105 South Seventh Street
Philadelphia, Pennsylvania 19106
(215) 597-7791
Delaware, District of Columbia, Maryland, Pennsylvania, Virgnia, and West Virginia

Region IV
1375 Peachtree Street, N. E.
Atlanta, Georgia 30309
(404) 257-2391
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee

Region V
300 South Wacker Drive
24th Floor
Chicago, Illinois 60606
(312) 372-6098
Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin

Region VI
Federal Regional Center
Room 206
800 North Loop 288
Denton, Texas 76201
(817) 749-9127
Arkansas, Louisiana, New Mexico, Oklahoma, and Texas

Region VII
911 Walnut Street, Room 300
Kansas City, Missouri 64106
(816) 758-2161
Iowa, Kansas, Missouri, and Nebraska

Region VIII
Denver Regional Center, Building 710
P. O. Box 25267
Denver, Colorado 80225-0267
(303) 322-4380
Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming

Region IX
Building 105
Presidio of San Francisco, California 94129
(415) 556-9840
Arizona, California, Hawaii, and Nevada

Region X
Federal Regional Center
130 228th Street, S. W.
Bothel, Washington 98021-9796
(206) 396-0282
Alaska, Idaho, Oregon, and Washington

State Coordinating Agencies for Flood Insurance

Alabama Department of Economics and Community Affairs
State Planning Division
P. O. Box 2939
3465 Norman Bridge Road
Montgomery, Alabama 36105-0939
(205) 284-8735

Alaska Department of Community and Regional Affairs
Division of Municipal and Regional Affairs
949 East 36 Avenue
Suite 400
Anchorage, Alaska 99508
(907) 561-8586

Arizona Department of Water Resources
Flood Control Branch
99 East Virginia, Second Floor
Phoenix, Arizona 85004
(602) 255-1566

Arkansas Soil and Water Conservation Commission
#l Capitol Mall, Suite 2D
Little Rock, Arkansas 72201
(501) 371-1611

California Department of Water Resources
P. O. Box 388
Sacramento, California 95802
(916) 445-6249

Colorado Water Conservation Board
State Centennial Building
1313 Sherman Street, Room 823
Denver, Colorado 80203
(303) 866-3441

Connecticut Department of Environmental Protection
Water Resources Unit
165 Capitol Avenue
Hartford, Connecticut 06106
(203) 566-7245

Delaware Department of Natural and Environmental Control
Division of Soil and Water Conservation
Richardson and Robbins Building
89 Kings Highway
P. O. Box 1401
Dover, Delaware 19903
(302) 736-4411

District of Columbia Department of Consumer Regulatory Affairs
614 H Street, N. W.
Washington, D. C. 20001
(202) 727-7577

Florida Department of Community Affairs
Division of Resource Planning and Management
2571 Executive Center Circle East
Tallahassee, Florida 32301
(904) 488-9210

Georgia Department of Natural Resources
19 Martin Luther King, Jr. Drive, S. W.
Room 400
Atlanta, Georgia 30334
(404) 656-3214

Guam Office of Civil Defense
P. O. Box 2877
Agana, Guam 96910
(011-671) 477-9841

Hawaii Board of Land and Natural Resources
Department of Land and Natural Resources
P. O. Box 373
Honolulu, Hawaii 96809
(808) 548-7539

Idaho Department of Water Resources
State House
Boise, Idaho 83720
(208) 334-4470

Illinois Department of Transportation
Division of Water Resources
Local Flood Plain Programs
300 North State Street, Room 1010
Chicago, Illinois 60610
(312) 793-3864

Indiana Department of Natural Resources
608 State Office Building
Indianapolis, Indiana 46204
(317) 232-4160

Iowa Department of Water, Air and Waste Management
Wallace State Office Building
Des Moines, Iowa 50319
(515) 281-5029

Kansas State Board of Agriculture
Division of Water Resources
109 Southwest Ninth Street
Topeka, Kansas 66612
(913) 296-3717

Kentucky Department of Natural Resources
Division of Water
18 Reilly Road
Fort Boone Plaza
Frankfort, Kentucky 40601
(502) 564-3410

Louisiana Department of Urban and Community Affairs
P. O. Box 44455, Capitol Station
Baton Rouge, Louisiana 70804
(504) 925-3730

Maine Bureau of Civil Emergency Preparedness
State House
187 State Street
Augusta, Maine 04333
(207) 289-3154

Maryland Department of Natural Resources
Water Resources Administration
Tawes State Office Building D-2
Annapolis, Maryland 21401
(301) 269-3826

Massachusetts Water Resources Commission
Division of Water Resources
State Office Building
100 Cambridge Street
Boston, Massachusetts 02202
(617) 727-3267

Michigan Department of Natural Resources
Water Management Division
P. O. Box 30028
Lansing, Michigan 48909
(517) 373-3930

Minnesota Department of Natural Resources
Division of Waters
444 LaFayette Road
St. Paul, Minnesota 55101
(612) 296-9226

Mississippi Research and Development Center
3825 Ridgewood Road
Jackson, Mississippi 39211
(601) 982-6376

Missouri Department of Natural Resources
1101 R. Southwest Boulevard
P. O. Box 1368
Jefferson City, Missouri 65102
(314) 751-4932

Montana Department of Natural Resources and Conservation
32 South Ewing Street
Helena, Montana 59601
(406) 444-6646

Nebraska Natural Resources Commission
P. O. Box 94876
Lincoln, Nebraska 68509
(402) 471-2081

Nevada Division of Emergency Management
Capitol Complex
Carson City, Nevada 89710
(702) 885-4240

New Hampshire Office of State Planning
2 1/2 Beacon Street
Concord, New Hampshire 03301
(603) 271-2231

New Jersey Department of Environmental Protection
Division of Water Resources
P. O. Box CN 029
Trenton, New Jersey 08625
(609) 292-2296

New Mexico State Engineer's Office
Bataan Memorial Building
Santa Fe, New Mexico 97501
(505) 827-6140

New York Department of Environmental Conservation
Flood Protection Bureau
50 Wolf Road, Room 422
Albany, New York 12233
(518) 457-3157

North Carolina Department of Natural Resources and Community Development
Division of Community Assistance
P. O. Box 27687
Raleigh, North Carolina 27611
(919) 733-2850

North Dakota State Water Commission
State Office Building
900 East Boulevard
Bismarck, North Dakota 58505
(701) 224-2750

Ohio Department of Natural Resources
Flood Plain Planning Unit
Fountain Square
Columbus, Ohio 43224
(614) 265-6755

Oklahoma Water Resources Board
10th and Stonewall, I2th Floor
Oklahoma City, Oklahoma 73105
(405) 271-2533

Oregon Department of Land Conservation and Development
1175 Court Street, N. E.
Salem, Oregon 97310
(503) 378-2332

Pennsylvania Department of Community Affairs
551 Forum Building, Room 317
Harrisburg, Pennsylvania 17120
(717) 787-7400

Puerto Rico Planning Board
P. O. Box 41119, Minillas Station
Santurce, Puerto Rico 09940
(809) 726-7110

Rhode Island Office of State Planning
Statewide Planning Program
265 Melrose Street
Providence, Rhode Island 02907
(401) 277-2656

South Carolina Water Resources Commission
3830 Forest Drive
P. O. Box 4440
Columbia, South Carolina 29240
(803) 758-2514

South Dakota Department of Military and Veterans Affairs
Division of Emergency and Disaster
State Capitol
Pierre, South Dakota 57501
(605) 773-3231

Tennessee Department of Economic and Community Development
Division of Local Planning
1800 James K. Polk Office Building
505 Deaderick Street
Nashville, Tennessee 37219
(615) 741-2211

Texas Department of Water Resources
P. O. Box 13087, Capitol Station
1700 North Congress Avenue
Austin, Texas 78711
(512) 475-2171

Utah Office of Comprehensive Emergency Management
1543 Sunnyside Avenue
Salt Lake City, Utah 84108
(801) 533-5271

Vermont Environmental Conservation Agency
Division of Water Resources
State Office Building
Montpelier, Vermont 05602
(802) 828-2761

Virginia State Water Control Board
P. O. Box 11143
Richmond, Virginia 23230
(804) 257-0075

Virgin Islands Disaster Preparedness Office
Box 1208
St. Thomas, Virgin Islands 00801
(809) 774-6555

Washington Department of Ecology
Mail Stop PV11
Olympia, Washington 98504
(206) 459-6288

West Virginia Office of Emergency Services
Capitol Building, Room EB-80
Charleston, West Virginia 25305
(304) 348-3831

Department of Natural Resources
Flood Plain-Shoreland Management Section
P. O. Box 7921
Madison, Wisconsin 53707
(608) 266-1926

Wyoming Disaster and Civil Defense Agency
P. O. Box 1709
Cheyenne, Wyoming 82003
(307) 777-7566

APPENDIX C

Sources of Flood Information

To develop an effective manufactured home installation strategy applicable to a flood hazard area, several hydrologic factors must be evaluated. These include the regulatory floodplain boundaries and the anticipated flooding characteristics for the site such as depth, velocity, duration, rate-of-rise, and frequency. Various sources of this information are available. Also, there are methods by which portions of such information can be individually developed.

As part of its National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) develops Flood Insurance Studies (FISs) which will often contain the most current and detailed information that is available for a community. Such studies can include a Flood Insurance Rate Map (FIRM), a Flood Boundary and Floodway Map (FBFM) and a FIS report, from which the following information can be obtained:

- Floodplain and floodway boundaries
- Stream profiles that show the elevations of the 100-year or "base" flood (the flood that has a one-percent chance of being equalled or exceeded in any given year) and other flood events
- Mapped base flood elevations which, in combination with other data, can be used to develop flood depths for a specific site
- Flood velocity data
- Flood frequency data
- Flood discharge data
- Historical flood information

FISs can be extremely valuable sources of portions of the information necessary to evaluate a potential manufactured home site. The specific hydrologic data elements, and ways to obtain them, are described below.

Flood Hazard Boundaries—Boundaries for the different degrees and types of flooding, including floodways, floodway fringe, coastal high hazard areas, coastal fringe, and shallow flooding areas, must be identified. Flood hazard boundaries are significant because they determine the specific flood hazard zones that are part of a proposed development site or that will influence development on the site. In addition, boundaries indicate where floodplain management regulations and flood insurance requirements, apply to the site. Flood hazard boundary data can be obtained from FBFMs, FIRMs, and floodplain maps or can be developed from topographic maps, zoning maps, aerial photographs, and related hydrologic data.

Flood Depths—Flood depths are determined by the difference between water surface elevation at times of flooding and normal ground surface elevations. This information is important both in determining the elevations at which flood damage is likely to occur and in defining the appropriate elevations for flood insurance and floodplain management regulations. Flood depths also influence the hydrostatic forces that are in effect during flooding, including the horizontal loads that can cause lateral displacement or overturning, and the vertical loads that can cause uplift and flotation. Flood depths can be derived by using a FIRM showing base flood elevations in combination with a topographic map depicting ground elevations for a particular site. Flood depth data is also available from various technical studies that include flood elevations, water surface profiles, or stream and coast cross-sections. In the absence of official reports, information on flood depths can be obtained from site survey and historical records.

Flood Water Velocity—The average and maximum velocity of floodwater is important in determining hydrodynamic forces, which influence horizontal loads in excess of hydrostatic loads. Velocity also affects the magnitude of debris impact loads (i.e., force of floating objects carried by floodwaters), and can increase erosion and affect soil stability on slopes. Data on water velocity is listed in Floodway Data Tables often included in FIS reports and is available from the various floodplain technical studies or can be determined by special hydrologic studies. Velocity can also be calculated by assuming floodwaters to be at a uniform flow, estimating some floodplain characteristics, and using Manning's Equation:

$$V = \frac{1.49\,(A/P)^{2/3}\,S^{1/2}}{n}$$

where: V = Average flow velocity (feet per second)

A = Cross-sectional flow area $(\text{feet})^2$

P = Wetted perimeter of A (feet)

S = Bed slope (feet/feet) (use average ground surface slope within a reach from approximately one-half mile upstream to approximately one-half mile downstream)

n = Manning's channel roughness coefficient

Frequency—Frequency of flooding is a major consideration in the evaluation of potential installation sites. Frequency of flooding is the probability (in percent) that a random flood event will equal or exceed a specified magnitude in a given time period. Manufactured homes sited at lower elevations near a flooding source will likely have a higher frequency of flooding than those located on higher ground away from the flooding source. Flood frequency information is included in FIS reports and other technical floodplain studies. Frequency of flooding can also be statistically determined using historical records of flooding at the location under consideration.

Rate of Rise—The rate of rise of a flood is an expression of how rapidly water depth increases during a flooding event. This factor is important in evaluating buoyancy hazards and investigating the feasibility of an evacuation plan. The rate of rise of flood- waters can be derived from a stream flow hydrograph that relates flooding depth to time for the area under consideration. Information required to determine the rate of rise may also be obtained from existing hydrologic studies, on-site investigations, historical records, and local civil defense offices.

Duration—The duration of flood inundation, which is a function of the rate of rise and fall of water, has several important influences on a manufactured home installation. Duration influences the saturation of soils and building materials, the amount of seepage, and the length of time that a manufactured home might be inaccessible. The various floodplain technical studies and historical records are sources of information concerning duration of flooding.

The following tables provide sources of various types of information and assistance.

FLOOD PLAIN MANAGEMENT SERVICES

FLOOD PLAIN AGENCIES / DATA TYPE	Floodwater Control	Floodproofing Information	Preserve Channel Capacity	Development Regulations	Land Use Controls	Public Information	Flood Fighting	Post-Flood Relief	Flood Warning Systems
• Federal Emergency Management Agency		•		•		•	•	•	
• U.S. Army Corps of Engineers	•	•	•	•		•	•	•	•
• U.S. Soil Conservation Service	•	•	•			•		•	
• Department of Housing and Urban Development				•				•	
• National Oceanic and Atmospheric Adminstration						•			•
• U.S. Geological Survey						•			
• Federal Highway Administration	•		•				•		
• State Floodplain Management Coordinating Agency	•	•	•	•	•	•			
• Regional Authorities	•	•	•	•		•	•	•	
• Local Government Planning Agencies				•	•	•			

SUMMARY OF HYDROLOGIC DATA SOURCES

AGENCIES / DATA TYPE	Coastal Surveys and Reports	Flood Control Measure	Flood Boundary Maps	Flood Insurance Rate Maps	Floodplain Information Reports and Technological Studies	Flood Records & Probabilities	Hydrologic Atlases	National Flood Ins. Program Regulations	State Floodplain Regulations	Technical Assistance	Topographic Maps	Zoning Ordinances and Maps
• Local government planning agency or municipal engineer	•	•	•	•	•	•		•	•	•	•	•
• State floodplain management coordinating agency	•	•	•	•		•		•	•	•		
• Federal Emergency Management Agency	•	•	•	•				•		•		
• National Oceanic and Atmospheric Administration (Department of Commerce)	•				•	•						
• Soil Conservation Service (U.S. Dept of Agriculture)		•			•	•						
• U.S. Army Corps of Engineers (Department of Defense)	•	•	•	•	•	•				•	•	•
• U.S. Geological Survey (Department of the Interior)					•	•	•				•	
• Regional authorities (e.g. T.V.A.)		•			•	•				•	•	

APPENDIX D Calculational Procedures for Elevated Foundation Design

As presented in Chapter IV, the minimum recommended design criteria are based on design conditions and data appropriate for the context of the manual. The intent of Chapter IV is to show the selection of elevated foundation components and materials that when assembled would provide sufficient design capacity to withstand the anticipated loads. Recognizing that such a presentation reduces the applicability to certain possible design conditions, this appendix provides the calculational procedures used as a basis in the manual. For ease of use and consistency with the manual, the presentation in this appendix follows the outline of Section B of Chapter IV.

For the purposes of this appendix, the following terminology is applicable.

A_c = Vertical member area (in^2)

A_f = Floor area (ft^2)

A_n = Total net area of wood member (in^2)

A_p = Pier area (in^2)

A_r = Roof area including eaves (ft^2)

a = Chassis I-beam spacing (in)

C_s = Lag screw pullout capacity (lb/in)

D_ℓ = Dead load of manufactured home (psf)

d = Vertical member diameter (in)

E = Modulus of elasticity (psi)

e = Distance from center to center of chassis I-beam to vertical member (in)

F_b = Bending stress (psi)

F'_b = Bending stress (psi) corrected for conditions of service

F_c = Compressive strength of wood (psi)

F'_c = Compressive strength of wood (psi) corrected for conditions of service

F_ℓ = Floor live load of manufactured home (psf)

F_r = Load per vertical member where roof load governs (lb)

F_t = Allowable working stress of wood in tension (psi)

F_w = Load per vertical member where wind load governs (lb)

f'_m = Concrete strength (psi)

h = Outside height of manufactured home including perimeter rail and chassis I-beam (ft)

L = Outside length of manufactured home (ft)

L_p = Lag screw penetration length (in)

L_w = Vertical load due to wind (lb)

ℓ = Total length of vertical member (in)

η = Number of vertical members (load points)

P = Vertical member capacity (lb)

Q = Bolt design capacity (lb)

R_ℓ = Roof live load (psf)

s = Vertical member spacing (ft)

S_x = Section modulus (in^3)

W = Outside width of manufactured home (ft)

W_ℓ = Lateral wind load (psf)

W'_ℓ = Lateral wind load per vertical member (lb)

W^*_ℓ = Lateral wind load adjusted parallel to bracing (lb)

W_u = Uplift wind load (psf)

W'_u = Uplift wind load per vertical member (lb)

Vertical Member Loads

The vertical load on each elevating member from Table 4.10 must be determined for two design conditions: 1) where roof live load governs and 2) where wind load governs.

For the first condition above, roof live load, dead load, and floor load act vertically downward through the chassis I-beam. This load (F_r) is determined as follows:

$$F_r = \frac{[(R_\ell)(A_r) + (D_\ell + F_\ell)(A_f)]}{\eta}$$

Where:

F_r = Load per vertical member (lb)

R_ℓ = Roof live load (psf)

$\tilde{A}_r$ = Roof area including eaves (ft^2)

D_ℓ = Dead load (psf)

F_ℓ = Floor live load (psf)

A_f = Floor area (ft^2)

η = Number of vertical members (load points)

For the second condition above, the lateral wind load is transferred to the chassis I-beam and the dead load and floor live load act vertically downward through the chassis I-beam. This load (F_w) is determined as follows:

$$F_w = \frac{L_w + (D_\ell + F_\ell)(A_f)}{\eta}$$

Where:

F_w = Load per vertical member (lb)

D_ℓ = Dead load (psf)

F_ℓ = Floor live load (psf)

A_f = Floor area (ft^2)

η = Number of vertical members (load points)

L_w = Vertical load due to wind (lb)

The vertical load due to wind is calculated as follows:

$$L_w = \frac{[(h/2)(12)(W_\ell)(L)(h)]}{a}$$

Where:

h = Outside height of manufactured home, including perimeter rail and chassis I-beam (ft)

W_ℓ = Lateral wind load (psf)

L = Outside length of manufactured home (ft)

a = Chassis I-beam spacing (in)

As discussed in Section B of Chapter IV, the following design conditions were used.

R_ℓ = 20, 30 or 40 psf based on roof live load zone (figure 4.1)

A_r = Width (W) X length (L) (including eaves)

D_ℓ = 20 psf

F_ℓ = 40 psf

A_f = Width (W) X length (L)

h = 9.75 ft.

W_ℓ = 15 or 25 psf based on wind load zone (Figure 4.2)

a = 75 1/2 in., 82 in., and 99 in.

s = 5, 6, 7, 8, 9, and 10 ft.

Pier Design

As presented in Section B of Chapter IV, various pier designs in Table 4.11 are recommended based on the anticipated loads which impact the manufactured home and are transferred to the pier. The recommended pier designs were determined using the interaction equation as follows:

$$1.33 = \frac{fa}{Fa} + \frac{fb}{Fb}$$

Where:

f_a = computed axial stress in psi
= [W x s x 60] ÷ Ap
Where:
W = Outside width of manufactured home (ft)
s = Vertical member spacing (ft)
A_p = Cross sectional area of pier (in^2)

fb = Horizontal loading in psi
= [W_ℓ x h x s x ℓ x 12] ÷ S_x
Where:
W_ℓ = Lateral windload (psf)
h = Outside height of manufactured home (ft)
s = Vertical member spacing (ft)
S_x = Section modulus of pier (in^3)
ℓ = Length of pier (ft)

F_a = 0.20 f′m

F_b = 0.30 f′m
Where:
f′m = Strength of concrete (psi)

The following design conditions were used in calculating the acceptable conditions under which pier failure would not occur for the pier designs in Section B of Chapter IV.

W = 12 and 14 ft.

s = 5, 6, 7, 8, 9, and 10 ft.

W_ℓ = 15 and 25 psf.

f′m = 1500 and 2500 psi.

ℓ = 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 ft.

S_x = Based on pier designs A-F

A_p = Based on pier designs A-F

Vertical Support Members (wood posts/piles)

Depending upon the anticipated loading to be transferred to the vertical support member, it is necessary to determine the capacity of a given vertical member. In determining the values in Tables 4.13 to 4.16, it was necessary to apply beam/column theory and solve for the capacity of a given member under various design and load conditions. This capacity is determined as follows:

$$1/P = \left(\frac{1}{A_c F'_c} + \frac{(\ell)(K)}{S_x F'_b} \right)$$

Where:

P = Vertical member capacity (lb)

A_c = Area of the vertical member (in^2)
= d^2 for square members
= $\frac{\pi d^2}{4}$ for round members
Where:
d = diameter (in)

ℓ = Total length of the vertical member above *and* below grade (in) including scour allowance from Table 4.5

S_x = Section modulus of the vertical member (in^3)
= $\frac{(bd^2)}{6}$ for square members,
= $\frac{\pi r^2}{4}$ for round members
Where:
r = radius (in)
d = depth (in)
b = base (in)

F'_b = Bending stress of vertical member modified for moisture, duration and service conditions (psi)

K = A/B
Where:

$$A = \frac{(h)(W\ell)}{2} \text{ and}$$

$$B = \frac{(D\ell \times F\ell)(W)}{2} + \left[\frac{(h^2/2)\ (W_L)}{a}\right]\left(\frac{(W\text{-}e)}{W}\right)$$

Where:

$$E = \frac{(w + 30'') - a}{2}$$

F'_c = Compressive strength of vertical member (psi)

if $\ell/d \leq 11$, then $F'_c = 625$ psi

if $11 < \ell/d < K'$, where $K' = 0.671 \sqrt{\frac{E}{F_c \propto}}$

then $F'_c = 625\ (\propto) \left[1 - 1/3 \left(\frac{\ell/d}{K'}\right)^4\right]$

if $\ell/d = K'$, then $F'_c = 625(2/3)$

if $\ell/d > K'$ and ≤ 50, then $F'_c = \frac{0.3E}{(\ell/d)^2}$

E = Modulus of elasticity (psi)

$\propto$ = 1.0

The following design conditions were used in calculating the data provided in Tables 4.13 – 4.16

$D\ell$ = 20 psf

$F\ell$ = 40 psf

$W\ell$ = 15 and 25 psf

W = 12 and 14 ft.

ℓ = 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168, 180, 192, 204, 216, 228, and 240 in.

d = 3½, 5½, 7½, 9½, and 11½ in. (square members)

d = 4, 6, 8, 10, and 12 in. (round members)

e = 37½, 46 and 49¼ in.* for W = 12 ft. and a = 99 in., 82 in., and 75½ in. respectively

e = 49½, 58, and 61¼ in.* for W = 14 ft. and a = 99 in., 82 in., and 75½ in. respectively

*Includes 30 in. additional width to allow for clearance between manufactured home side and vertical member.

F'_b = 915 psi = [(800 psi) X (1.33 duration) X (0.86 moisture)]

E = 1,000,000 psi

α = 1.00

h = 9.75 ft.

Horizontal Support Beams

The application of the vertical member loads to the elevated foundation requires that the horizontal support beams be capable of sustaining the anticipated loading. The recommended horizontal beam size is determined as follows.

$$\text{Min. } S_x = \frac{(F_r)(e)}{F'_b} \quad \text{or} \quad \frac{(F_w)(e)}{F'_b} \quad \text{whichever is greater}$$

Where:

$S_x = \frac{(b)(d)^2}{6}$ (in³)

F_r or F_w = Vertical force (Table 4.10)

e = Distance from I-beam to vertical member (in)

F_b = bending stress of wood (psi)

Subsequent to a determination of the minimum S_x required for each design condition, the required size and number of horizontal beams can be found.

The following values were used in this calculation.

F_r or F_w = Forces provided in Table 4.10 for the loads, and design dimensions shown

e = 37½, 46 and 49¼ in.* for w = 12 ft. and a = 99 in., 82., and 75½ in. respectively

e = 49½, 58 and 61¼ in.* for w = 14 ft. and a = 99 in., 82 in., and 75½ in. respectively

*Includes 30 in. additional width to allow for clearance between manufactured home and vertical member.

F'_b = 1207.5 psi = [(1250 psi)(1.15 duration)(0.84 vertical bending)]

Cross Bracing

Cross bracing will improve the stability of the elevated foundation against lateral wind loading. The required number and size of cross bracing members is determined as follows:

$$A_\eta = \frac{[(h)(L)(W_\ell)]/\text{Cos} \measuredangle}{F_t}$$

Where:

A_η	=	*Total* net area of cross bracing required (in²)
h	=	Manufactured home height (ft)
L	=	Manufactured home length (ft)
W_ℓ	=	Design wind load (psi)
Cos $\measuredangle$	=	Cosine of angle between cross bracing and horizontal beam.
F_t	=	Allowable working stress in tension of wood (psi)

Subsequent to calculating the minimum net area, the number of vertical members cross braced is divided into A_η for each member and a size member chosen having at least that cross sectional area.

The following design values were used in developing the criteria for Tables 4.18 and 4.19.

h	=	9.75 ft.
L	=	32, 40, 48, 52, 56, 60, 66, and 72 ft.
W_ℓ	=	15 and 25 psf.
Cos $\measuredangle$	=	Vertical member height above grade at 3, 4, 5, 6, 7, 8, and 10 ft. with a 17 ft. space between vertical members under the manufactured home
F_t	=	531.3 psi.

End Bracing

There is a need to improve the lateral stability of the elevated foundation against lateral wind loading on the end of the manufactured home. Each end is required to be braced and the size of end bracing is determined as follows:

$$A_\eta = \frac{[(h)(W)(W_\ell)]/\text{Cos} \measuredangle}{F_t}$$

Where:

A_η	=	*Total* net area of end bracing required (in²)
h	=	Manufactured home height (ft)
W	=	Manufactured home length (ft)
W_ℓ	=	Design wind load (psi)
Cos $\measuredangle$	=	Cosine of angle between end bracing and the horizontal
F_t	=	Allowable working stress in tension of wood (psi)

Subsequent to calculating the minimum net area, the value is divided by two to represent the two members under tensile load at the loaded end of the manufactured home and a member size chosen having at least that cross sectional area.

The following design values were used in developing the criteria for Table 4.20.

h	=	9.75 ft.
W	=	12 and 14 ft.
W_ℓ	=	15 and 25 psf.
Cos $\measuredangle$	=	Vertical member height above grade at 3, 4, 5, 6, 7, 8, and 10 ft. and vertical support spacings of 5, 6, 7, 8, 9, and 10 ft.
F_t	=	531.3 psi.

Connections

Vertical Member to Horizontal Beam

The vertical member loads presented in Table 4.10 are directly transferred to the connection of the vertical member and horizontal beam. The number of bolts of a given size are determined as follows:

F_r/Q or F_w/Q (whichever is greater)

F_r or F_w	=	Vertical member load (lb) from Table 4.10 or calculated for other conditions
Q	=	Bolt design capacity (lb)

The bolt design capacity is based on the type of wood, length of bolt in the horizontal beam, diameter of bolt and direction of load to wood grain.

The values in Tables 4.21 and 4.22 of the manual were derived from the vertical member loads in Table 4.10 at the stated design conditions and the following bolt design values for spruce-pine-fir, setka spruce, yellow poplar, and eastern spruce and lodgepole pine.

Q - Bolt Design Value (lb)

Horizontal Beam Size

Bolt Diameter (in)	2@3 in.	4@2 in.	4@3 in.
5/8	990.0	1012.5	-
3/4	1170.0	1295.0	-
7/8	1290.0	1505.0	1[illegible]5.0
1	1410.0	1687.5	2147.5
1 1/4	1655.0	1985.0	3117.5

To be capable of supporting the imposed load the total bolt capacity (bolt design value x no. bolts) must be greater than or equal to the vertical load from Table 4.10 or calculated as previously discussed.

Chassis I-beams

The lag screws used to connect the chassis I-beam clips to the horizontal beam must be capable of resisting uplift and shear loads resulting from wind.

The lateral wind load per vertical member is calculated as follows:

$$W'_\ell = \frac{\left[\left(\frac{h}{2}\right)(12)(W_\ell)(s)(h)\right]}{a}$$

Where:

W'_ℓ	=	Lateral wind load per vertical member (lb)
h	=	Manufactured home height (ft)
W_ℓ	=	Lateral wind load (psf)
s	=	Vertical member spacing lengthwise (ft)
a	=	I-beam spacing

The uplift wind load per vertical member is calculated as follows:

$$W'_u = \frac{[(W_u)(s)(W)] + 2.5W_u[(s)(W + 2)]}{2}$$

Where:

W'_u = Uplift wind load per vertical member (lb)

W = manufactured home width (ft)

W_u = Uplift wind load (psf)

s = Vertical member spacing lengthwise (ft)

The pullout capacity (C_S) of 1/2 in. lag screws with wood having a specific gravity of 0.42 is 291 lb. per inch of shank diameter. To determine the required penetration length (lb) per screw, the following calculation is used.

$$L_p = \frac{W'_\ell + W'_u}{(4)\ (291)}$$

In calculating the required penetration length the following values were used.

h = 9.75 ft.

W_ℓ = 15 and 25 psf.

s = 5, 6, 7, 8, 9, and 10 ft.

a = 75½ in.

W = 14 ft.

W_u = 9 and 15 psf.

Cross and End Bracing

To determine the number and diameter of bolts needed for cross and end bracing, the lateral wind load, which acts horizontally, must be adjusted to act parallel with the load bearing the bracing member as follows:

$$W^*_\ell = \frac{(h)(W_\ell)}{\sin \measuredangle}$$

Where:

W^*_ℓ = Adjusted load (lb./ft. home)

h = Manufactured home height (ft)

W_ℓ = Lateral wind load (psf)

$\sin \measuredangle$ = sine of the angle between horizontal and bracing member

In this calculation the following values were used.

h = 9.75 ft.

W_ℓ = 15 and 25 psf

$\sin \theta$ = Based on geometry of 12 ft. wide horizontal dimension and height of vertical member at 3, 4, 5, 6, 7, 8, and 10 ft. (corrected by subtracting 1 ft. to allow for horizontal beam depth)

Bolt capacity Table 4.25 was developed based on the type of wood previously described for vertical members and corrected for interpolation between capacity parallel and perpendicular to grain as follows:

$$Q = \left[\frac{(Q\perp)\ (Q//)}{[(Q//)(\cos^2\theta)] + [(Q\perp)(\sin^2\theta)]} \right] \times ½$$

Where:

Q = Bolt capacity as loaded (lb)

$Q\perp$ = Capacity perpendicular to grain (lb)

$Q_{//}$ = Capacity parallel to grain (lb)

θ = Angle between horizontal and diagonal member

The total number of bolts and size required per connection are determined as follows:

Number bolts = $W^{*}\ell/Q$

Having reviewed the methods and procedures utilized, one should appreciate the complexity of design for elevated foundations. Where additional details are necessary, different conditions apply or further design detail is required, publications such as those listed in Appendix A should be consulted. As noted in the manual, state and local regulations should be considered to determine provisions requiring design by a registered engineer.

APPENDIX E

Buoyancy and Drag Forces

Buoyancy

Based on the anticipated flood height, the resultant buoyancy force, and the load capacity of manufactured housing ground anchors, it is possible to determine the ground anchor spacing necessary to resist flotation. The vertical tie force (Tv), shown in Table E.1 can be divided into anchor capacity to yield the anchor spacing needed to resist the anticipated load. Minimum anchor spacings based on a 2,200 pound ground anchor capacity for given flood height differences and tie angles are shown in Table E.2. The shaded areas in the table indicate situations where the amount of anchorage is not feasible or would transfer loads to the floor or other portions of the manufactured home causing them to fail and damage the manufactured home. Note these ties are in addition to those recommended by the manufacturer or ANSI Standard A225.1-1982 for wind anchorage.

Note that where diagonal ties are used, the required tie spacing decreases and additional ties will be needed. In reviewing Tables E.1 and E.2, the effects of water height and tie angle on tie spacing are dramatically shown. On a 14 foot wide manufactured home, for instance, the number of ties increases by a factor of four if the difference in water height is increased from six to nine inches and diagonal ties at 45 degrees are used in lieu of vertical (90 degree) ties.

Limited testing of ground anchors in saturated soil has been undertaken. Of the testing conducted, a wide range of results have been achieved. Unless specific test results for the soil type of the site have been conducted for the particular anchor the above tie spacing values should be used. Where testing is performed the spacing values in Table E.2 can be adjusted to yield a new recommended minimum spacing as previously shown.

It is important to stress that these criteria for anchoring only apply to flooding forces due to buoyancy imposed on a manufactured home. Where wind forces are also anticipated, additional anchoring will be necessary and should be consistent with that required by state or local regulations addressing manufactured housing installations, the manufacturers instructions or ANSI Standard A225.1-1982.

Consider also the cost associated with anchoring in lieu of elevation. Using the economic information in Chapter V, ground anchors cost $35.00 to $75.00 installed. Referring to Table E.1 for a 15 inch difference in water height and 60 degree

Table E.1

VERTICAL TENSION (T_V)
(pounds)

Home Width (ft.)	Difference in Water Height (in.)[1]															
	1	2	3	4	5	6	9	12	15	18	21	24	30	36	42	48
12	-	-	-	4.8	36.0	67.2	160.8	254.4	348.0	441.6	535.2	628.8	816.0	1003.2	1190.4	1377.6
14	-	-	-	5.6	42.0	78.4	187.6	296.8	406.0	515.2	624.4	733.6	952.0	1170.4	1388.8	1607.2
24	-	-	-	9.6	72.0	124.4	321.6	508.8	696.0	883.2	1070.4	1257.6	1632.0	2006.4	2380.8	2755.2
28	-	-	-	11.2	84.0	156.8	375.2	593.6	812.0	1030.4	1248.8	1467.2	1904.0	2340.8	2777.6	3214.4

[1]Height of floodwater above underside of manufactured home minus height of floodwater inside the manufactured home ($h_1 - h_2$).

$F_b = h \times v \times w$ (lb./lin. ft. of home) where: $h = (h_1 - h_2)$ ft;
$v = 62.4$ lb./cu. ft.; w = width (ft)

$T_v = \frac{(F_b - Wt)}{2}$ (lb/lin. ft. of home per side) where: T_v = vertical tie force needed to overcome F_b;
Wt = weight of home at 20 lb./sq. ft.

Table E.2

MINIMUM SPACING BETWEEN GROUND ANCHORS[1]
(feet)

Home Width (ft.)	Tie Angle	Difference in Water Height (in.)[2]							
		6	9	12	15	18	24	30	36
12	90	32.74	13.68	8.65	6.32	4.98	3.50	2.70	2.19
	60	28.35	11.85	7.49	5.47	4.31	3.03	2.33	-
	45	23.15	9.67	6.11	4.47	3.52	2.47	-	-
	30	16.37	6.84	4.32	3.16	2.49	-	-	-
14	90	28.06	11.73	7.41	5.42	4.27	3.00	2.31	-
	60	24.30	10.16	6.42	4.69	3.70	2.60	2.00	-
	45	19.84	8.29	5.24	3.83	3.02	2.13	-	-
	30	14.03	5.86	3.71	2.71	2.14	-	-	-
24	90	17.69	6.84	4.32	3.16	2.49	-	-	-
	60	15.32	5.92	3.74	2.74	2.16	-	-	-
	45	12.50	4.84	3.06	2.23	-	-	-	-
	30	8.84	3.42	2.16	-	-	-	-	-
28	90	14.03	5.86	3.71	2.71	2.14	-	-	-
	60	12.15	5.08	3.21	2.35	-	-	-	-
	45	9.92	4.15	2.62	-	-	-	-	-
	30	7.01	2.93	-	-	-	-	-	-

[1]Based on a 2200 pound ground anchor pull out capacity. Where spacing is less than or equal to 24 inches values are not provided.
[2]Difference in water height (in.) between the inside and outside of the manufactured home.

For soils where the actual ground anchor pull out capacity may be greater than or equal to 2200 pounds, and less than or equal to 3150 pounds, the values in Table E.2 may be proportionately increased.

$$\text{New Spacing} = \frac{\text{Spacing Above} \times \text{(Actual capacity pounds)}}{\text{2200 pounds}}$$

For instance if the soil had a pull out capacity of 3150 pounds and a 14 ft. home with a nine inch anticipated water height were to be anchored with vertical ties, the new spacing would be as follows:

$$\text{New Spacing} = \frac{11.73 \times 3150 \text{ lbs.}}{2200 \text{ lbs.}} = 16.80 \text{ ft.}$$

[2]Difference in water height (in.) between the inside and outside of the manufactured home.

tie angle, the cost due to additional anchoring is $14.93 to $31.98 per foot for a 14 foot wide manufactured home. Comparing this to the cost for earth fill, piles, or piers, it will be less costly to elevate the manufactured home two feet while concurrently reducing potential damage.

Drag

Drag forces will also result in additional anchoring requirements based on water height and velocity. While buoyancy forces exert an upward force on the anchoring system, drag forces exert a horizontal force which must also be counteracted through additional ties. From the anticipated drag force, as presented in Section B of Chapter IV and the capacity of ground anchors, it is possible to determine the necessary anchor spacing to resist any drag loads. The drag loads can be divided into the anchor capacity to yield the required anchor capacity to resist the anticipated vertical load. Calculated anchor spacings based on a 2,200 pound ground anchor capacity for given flood height, differences in tie angles, and velocity are presented in Table E.3.

The impracticality of anchoring a manufactured home in floodwaters imposing more than a nine to 12 inch exterior water height above the finished floor becomes apparent. Consequently, the manufactured home must be elevated above anticipated flooding.

Table E.3

MINIMUM SPACING BETWEEN GROUND ANCHORS[1]
(feet)

Velocity (fps)	Tie Angle	Height of Water (in.)[2]							
		6	9	12	15	18	24	30	36
3.0	60	-	-	-	-	-	-	-	-
	45	-	-	-	-	-	-	-	-
	30	-	-	-	-	-	-	38.47	32.06
4.0	60	-	-	-	-	-	-	37.48	31.23
	45	-	-	-	-	-	38.24	30.59	25.50
	30	-	-	-	-	36.07	27.05	21.64	18.04
5.0	60	-	-	-	-	39.98	29.98	23.99	19.99
	45	-	-	-	39.16	32.63	24.47	19.58	16.32
	30	-	-	34.62	27.70	23.08	17.31	13.85	11.54
6.0	60	-	-	-	33.32	27.76	20.82	16.66	13.88
	45	-	-	33.99	27.19	22.66	17.00	13.60	11.33
	30	-	32.06	24.04	19.24	16.03	12.02	9.62	8.02
8.0	60	-	31.23	23.43	18.74	15.62	11.71	9.37	7.81
	45	38.24	25.50	19.12	15.30	12.75	9.56	7.65	6.37
	30	27.05	18.04	13.52	10.82	9.02	6.76	5.41	4.51
10.0	60	29.98	19.99	14.99	11.99	9.99	7.50	6.00	5.00
	45	24.47	16.32	12.24	9.79	8.16	6.12	4.89	4.08
	30	17.31	11.54	8.66	6.93	5.77	4.33	3.46	2.89
12.0	60	20.82	13.88	10.41	8.33	6.94	5.21	4.16	3.47
	45	17.00	11.33	8.50	6.80	5.67	4.25	3.40	2.83
	30	12.02	8.02	6.01	4.81	4.01	3.01	2.40	2.00
15.0	60	13.33	8.88	6.66	5.33	4.44	3.33	2.67	2.22
	45	10.88	7.25	5.44	4.35	3.63	2.72	2.18	1.81
	30	7.69	5.13	3.85	3.08	2.56	1.92	1.54	1.28

[1]For manufactured home sited perpendicular to flow. Values not provided for spacing 40 feet or more.

[2]Height of water impacting the manufactured home from the bottom of the chassis I-beam.

APPENDIX F

Design Worksheet

The purpose of the design worksheet is to provide a format for developing a manufactured home installation design on a per section basis. Based on the information presented in the manual and a determination of the manufactured home and site specifics, the following worksheet can be completed. It can subsequently be used to determine installation arrangements and provide a basis for estimating their costs. Where appropriate, references to information in the manual are presented. To aid in completing the design worksheet, instructions are also provided. Part I addresses the design of the manufactured home foundation system. Part II addresses the associated costs for that design. Part III provides space to develop an installation design plan.

It is suggested that this worksheet be used to develop several designs and cost estimates so that a comparison can be made to determine an appropriate design strategy. Figure F.1 highlights those areas addressed by the design worksheet. The numbers in Figure F.1 refer to specific line numbers (Ln) in the design worksheet.

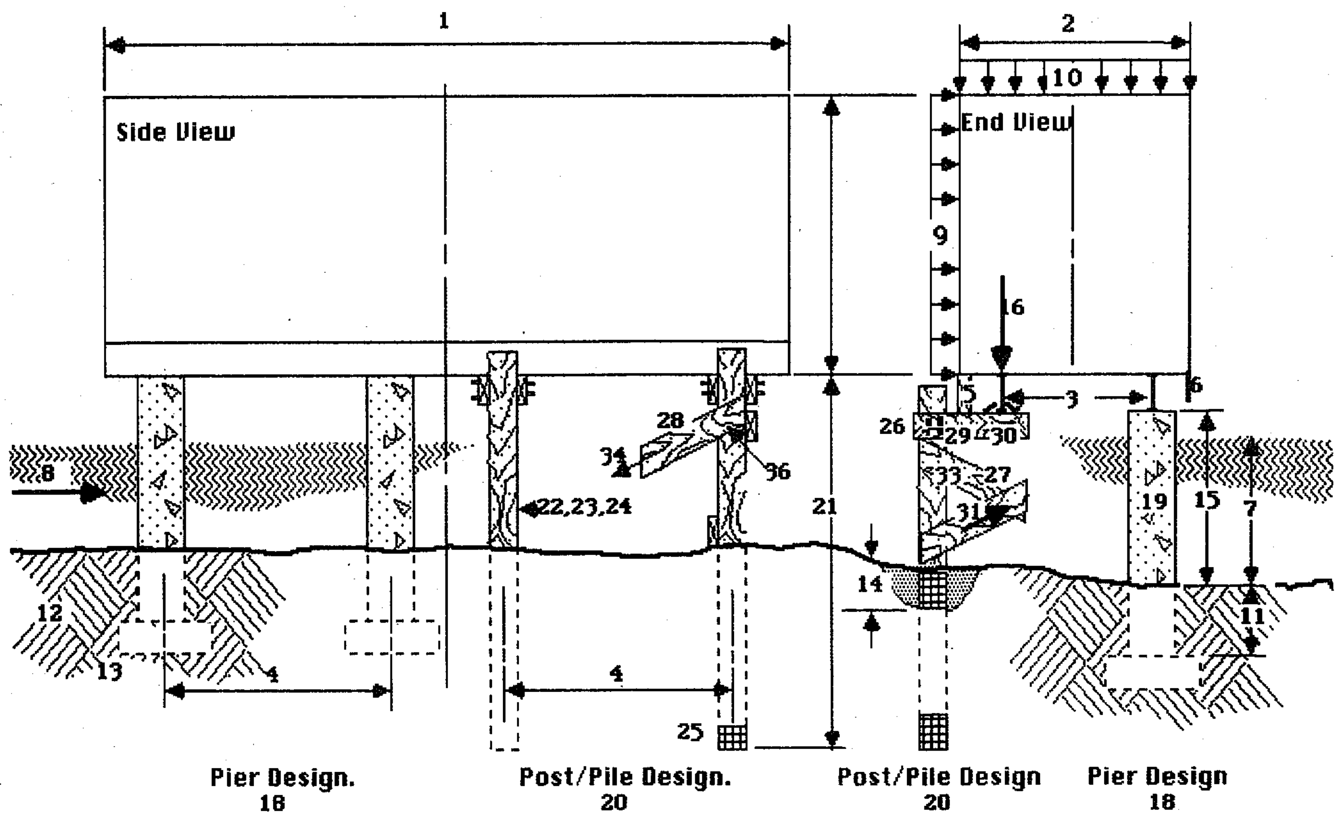

Figure F.1

DESIGN WORKSHEET

PART I

LINE No. (Ln)	ITEM DESCRIPTION	DATA ENTRY	NOTES
1.	MANUFACTURED HOME LENGTH (L)	ft.	MEASURED OVER EXTERIOR OF END WALLS
2.	MANUFACTURED HOME WIDTH (W)	ft.	MEASURED OVER EXTERIOR OF SIDE WALLS
3.	CHASSIS I-BEAM SPACING (a)	in.	℄ TO ℄ OF CHASSIS I-BEAMS
4.	SUPPORT SPACING (s)	ft.	$\leq$10 FT. OR MANUFACTURER'S DATA
5.	PERIMETER BLOCKING	Y N	IF YES REDUCE Ln 22 BY 5%
6.	OVER-THE-TOP TIES	Y N	
7.	MAX. DEPTH OF 100 YR. FLOOD	ft.	AS DISCUSSED IN APPENDIX C
8.	MAX. FLOOD VELOCITY	fps	AS DISCUSSED IN APPENDIX C
9.	WIND LOAD	psf	FIGURE 4.2 (PAGE 33)
10.	ROOF LIVE LOAD	psf	FIGURE 4.1 (PAGE 33)
11.	DEPTH TO FROSTLINE	ft.	
12.	TYPE OF SOIL		AS DISCUSSED ON PAGE 48
13.	BEARING CAPACITY OF SOIL	psf	AS DISCUSSED ON PAGE 48
14.	SCOUR DEPTH	ft.	TABLE 4.5 (PAGE 40)(ASSUME 12"ϕMEMBER)
15.	MAX. HT. TO BOTTOM OF CHASSIS I-BEAM	ft.	MUST BE $\geq$Ln 7 ENTRY
16.	VERT. MEMBER LOAD	lb.	TABLE 4.10 (PAGE 47)
17.	ELEVATION ON FILL	Y N	IF Ln 8 IS $\leq$10 fps
18.	ELEVATION ON PIERS	Y N	IF Ln 8 = 0 fps
19.	PIER DESIGN		ENTER A-F FROM TABLE 4.11 (PAGE 50)
20.	ELEVATION ON POSTS/PILES	Y N	
21.	MIN. VERT. MEMBER LENGTH	ft.	2 X (Ln 14 + Ln 15) NOTE THAT DIST. BELOW GRADE $\geq$6 ft.)
22.	VERT. MEMBER CAPACITY	lb.	TABLE 4.13 - 4.16. MUST BE $\geq$Ln 16
23.	VERT. MEMBER SIZE	in.	TABLE 4.13 - 4.16. IF $\neq$ 12" GO TO Ln 14 AND RECALCULATE ENTRY AND Lns 21, Ln 22 and 23
24.	VERT. MEMBER AREA	$ft.^2$	πr^2 IF ϕ AND d^2 IF □
25.	VERT. MEMBER UNIT LOAD	psf	Ln 16 $\div$ Ln 24. IF Ln 25 > Ln 13, ADD BEARING PAD, USE PILES OR REDUCE Ln 4 AND RECALCULATE Lns 16, 22, 23, 24 AND 25 UNTIL Ln 25 $\leq$ Ln 13
26.	No. & SIZE HORIZ. BEAMS	@ " x "	FROM TABLE 4.17 (PAGE 60)
27.	No. & SIZE CROSS BRACING	@ " x "	FROM TABLE 4.18 OR 4.19 (PAGES 61 & 62)
28.	SIZE END BRACING	" x "	FROM TABLE 4.20 (PAGE 62)
29.	No. & SIZE HORIZ. BEAM BOLTS	@ "	FROM TABLE 4.21 OR 4.22 (PAGES 63 & 64)
30.	CHASSIS I-BEAM LAG SCREWS	1/2" x "	FROM TABLE 4.25 (PAGE 65)
31.	CROSS BRACING LOAD	lb.	[TABLE 4.27 x Ln 1] $\div$ [No. Ln 27 x 2]
32.	BOLT CAPACITY	lb./bolt	FROM TABLE 4.26 (PAGE 66)
33.	No. BOLTS & SIZE PER CONNECTION	@ "	Ln 31 $\div$ Ln 32 (MUST BE $\geq$2)
34.	END BRACING LOAD	lb.	[TABLE 4.27 x Ln 2] $\div$ 2
35.	BOLT CAPACITY	lb./bolt	FROM TABLE 4.26 (PAGE 66)
36.	No. BOLTS & SIZE PER CONNECTION	@ "	Ln 34 $\div$ Ln 35 (MUST BE $\geq$2)

PART II

LINE No. (Ln)	MATERIALS	AMOUNT/ DESCRIPTION	UNIT COST	TOTAL COST
37.	CLEARING................................	$ft.^2$	@ $ $/ft.^2$	= $
38.	EXCAVATION..............................	cu.yd.	@ $ /cu.yd.	= $
39.	EARTH FILL..............................	cu.yd.	@ $ /cu.yd.	= $
40.	SITE GRADING............................	cu.yd.	@ $ /cu.yd.	= $
41.	ANCHORS.................................		@ $ ea.	= $
42.	PIERS-..................([Ln 1$\div$Ln 4]+1)x2=		@ $ ea.	= $
43.	POSTS-..................([Ln 1$\div$Ln 4]+1)x2=		@ $ ea.	= $

44.	PILES-..................([Ln 1÷Ln 4]+1)x2=		@ $ ______ ea.	= $
45.	HORIZ. BEAMS-..([Ln 1÷Ln 4]+1)x No. Ln 26=		@ $ ______ ea.	= $
46.	CROSS BRACING-..............No. Ln 27 x 2=		@ $ ______ ea.	= $
47.	END BRACING-................No. Ln 28 x 4=		@ $ ______ ea.	= $
48.	HORIZ. BEAM BOLTS-.(No.Ln 29xNo.Ln43or44)=		@ $ ______ ea.	= $
49.	I-BEAM LAG SCREWS-...(4x No. Ln 43 or 44)=		@ $ ______ ea.	= $
50.	CROSS BRACING BOLTS-(No.Ln 33xNo.Ln 27x4)=		@ $ ______ ea.	= $
51.	END BRACING BOLTS-..........(No. Ln 36x8)=		@ $ ______ ea.	= $
52.	JACKING			$
53.	UTILITIES			$
54.	STEPS			$
55.	SITE IMPROVEMENTS			$
56.	MISC.			$
57.	MISC.			$
58.	MISC.			$
59.	MISC.			$
60.	TOTAL ESTIMATED MATERIAL COST (ΣLn 37-59)			$
61.	LABOR ______ MAN HOURS		@ $ ______ /hr.	$
62.	TOTAL ESTIMATED COST (ΣLn 60 & 61)			$

PART III - DESIGN PLAN

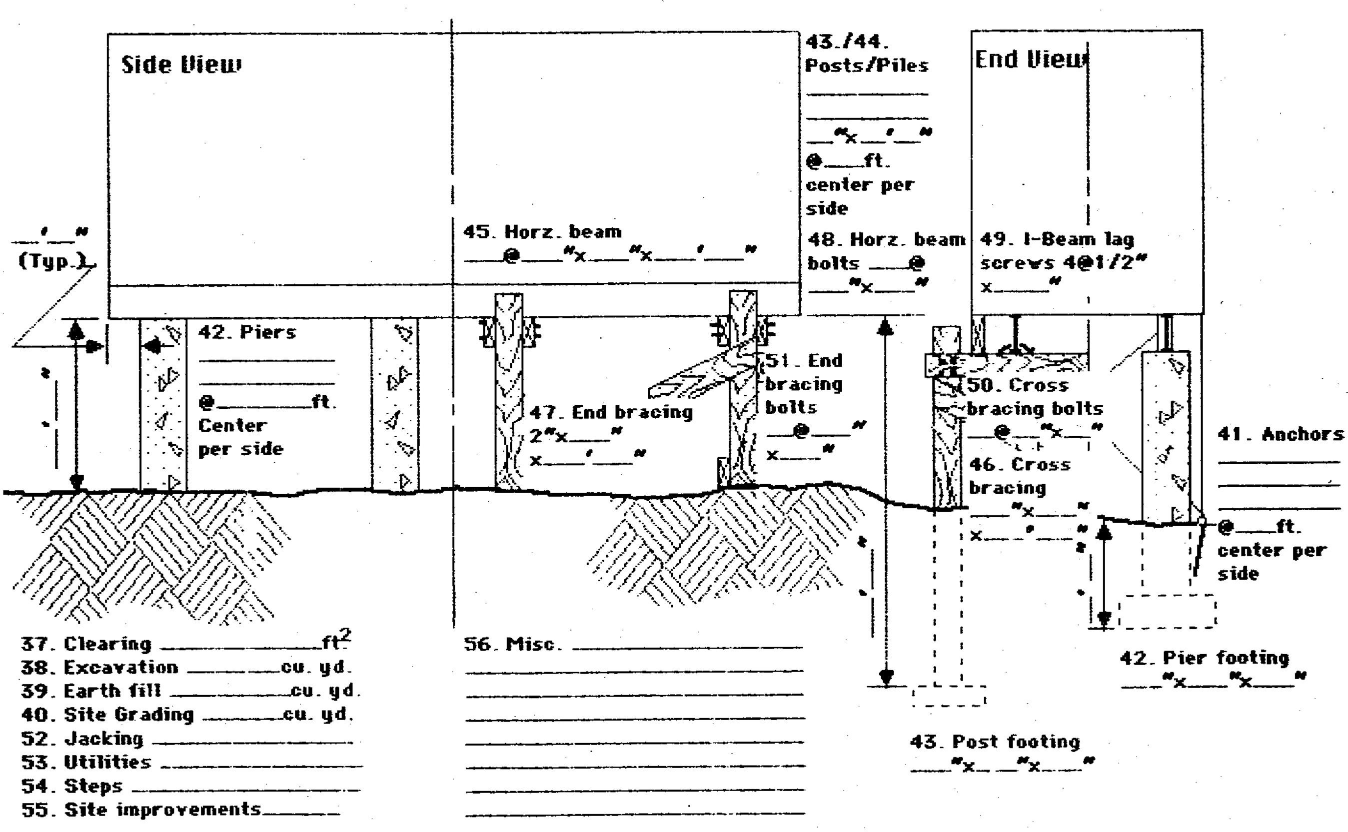

Figure F.2

PART I

LINE
No.
(Ln)

1. MANUFACTURED HOME LENGTH - Enter outside length (ft.) measured over exterior of end walls. This value is used in determining input to subsequent line numbers.

2. MANUFACTURED HOME WIDTH - Enter outside width (ft.) measured over exterior of side walls. This value is used in determining input to subsequent line numbers.

3. CHASSIS I-BEAM SPACING - Enter the distance (in.) from center to center of the chassis I-beams. If not available at the time of foundation design, use 75 1/2 inches.

4. SUPPORT SPACING - Enter the maximum distance between supports along length of manufactured home. Note that vertical member loading may necessitate a reduction in support spacing.

5. PERIMETER BLOCKING - If the manufacturer requires perimeter blocking, it must be provided and Line 22 must be reduced by 5%.

6. OVER-THE-TOP-TIES - If the manufactured home is equipped with over-the-top ties, they must be secured to the elevated foundation or ground anchors.

7. MAXIMUM DEPTH OF 100 YEAR FLOOD - Enter the depth (ft.) from the lowest natural grade level to the 100 year flood.

8. MAXIMUM FLOOD VELOCITY - Enter the maximum flood velocity (fps). This value is used in determining input to subsequent line numbers.

9. WIND LOAD - Based on geographical location and Figure 4.2, determine the appropriate wind load zone. The corresponding wind load (15 or 25 psf) is entered and will be used in determining input to subsequent line numbers.

10. ROOF LIVE LOAD - Based on geographical location and Figure 4.1, determine the appropriate roof live load zone. The corresponding roof live load (20, 30, or 40 psf) is entered and will be used in determining input to subsequent line numbers.

11. DEPTH TO FROSTLINE - Enter the depth (ft.) from natural grade to the frostline. This value is used in determining pier height, which is measured from the frostline.

12. TYPE OF SOIL - Enter the type of soil on the site. Where assistance is needed, contact the local building department or a soils engineer.

13. BEARING CAPACITY OF SOIL - Based on the type of soil in Line 12 and discussion in Chapter IV, enter the bearing capacity (psf) of the soil.

14. SCOUR DEPTH - Enter the anticipated scour depth (ft.) from Table 4.5 based on the Line 8 entry. Assume a 12 inch diameter member and if Line 23 results in a smaller diameter member being needed, Line 13 and subsequent entries may be recalculated.

15. MAXIMUM HEIGHT TO BOTTOM OF CHASSIS I-BEAM - Enter the desired height above natural grade (ft.) which must be greater than or equal to Line 7. This value is used in determining input to subsequent line numbers.

16. VERTICAL MEMBER LOAD - Enter the vertical member load (lb.) from Table 4.10 based on Line 2, 3, 4, 9, and 10 entries. Note the increase in load as the Line 4 entry increases. Therefore, consider reducing Line 4, until Line 15 is in the range of 3,500 to 5,000 pounds.

17. ELEVATION ON FILL - If the Line 8 entry is less than or equal to 10 fps, fill as discussed in Chapter IV can be considered using a conventional set-up with piers and ground anchors provided that Line 15 is greater than or equal to Line 7. Part II can be completed for the fill/conventional installation design.

18. ELEVATION ON PIERS - If the Line 7 entry is less than or equal to 10 feet and the Line 8 entry equals 0 fps, piers as discussed in Chapter IV can be considered.

19. PIER DESIGN - If Line 18 is yes, then use Table 4.11 to determine the appropriate pier design (A-F) from Figures 4.26 - 4.31. Part II can be completed for the pier design.

20. ELEVATION ON POSTS/PILES - If the elevation techniques in Lines 17 and 18 are not feasible, posts/piles as discussed in Chapter IV will be required.

21. MINIMUM VERTICAL MEMBER LENGTH - Calculate as follows: 2 x (Ln 14 + Ln 15). This value is the minimum vertical member length which is used in determining the required diameter of the vertical member in Line 23. Note that the depth below grade must be equal to the height above grade but not less than 6 feet.

22. VERTICAL MEMBER CAPACITY - Based on the information in Lines 2, 9, and 21, use Tables 4.13 - 4.16 to find a vertical member capacity greater than or equal to the value in Line 16. Note by decreasing Line 4, the value in Line 16 decreases as would the required value for vertical member capacity.

23. VERTICAL MEMBER SIZE - Enter the vertical member size from Tables 4.13 - 4.16 corresponding to the entry in Line 22. Note that if Line 23 is not equal to 12 inches, Lines 14, 21, 22, and 23 may be recalculated.

24. VERTICAL MEMBER AREA - Calculate the end area of the Line 23 entry. For round members area equals 3.14 x radius squared and for square members area equals diameter squared.

25. VERTICAL MEMBER UNIT LOAD - Calculate as follows: Line 16 divided by Line 24. This is the psf load through the bearing area of the vertical member. If less than or equal to the Line 13 entry, the soil capacity will support the foundation. If greater than the Line 13 entry, additional bearing area must be added under the vertical member, piles must be used, or Line 4 reduced and Lines 16, 22, 23, 24, and 25 recalculated.

26. NUMBER AND SIZE OF HORIZONTAL BEAMS - Based on the entries in Lines 2, 3, 4, 9, and 10, determine the number needed and the size of the horizontal support beams from Table 4.17.

27. NUMBER AND SIZE OF CROSS BRACING - Based on the entries in Lines 1, 9, and 15, determine the number needed and the size of the cross bracing from Table 4.18 or 4.19.

28. SIZE OF END BRACING - Based on the entries in Lines 4, 9, and 15, determine the size of the end bracing from Table 4.20.

29. NUMBER AND SIZE OF HORIZONTAL BEAM BOLTS - Based on the entries in Lines 2, 4, 9, 10, and 23, determine the number and size from Table 4.21 or 4.22. Note the bolt dimension criteria in Tables 4.23 and 4.24 must be followed in installation.

30. CHASSIS I-BEAM LAG SCREWS - Based on the entries in Lines 4 and 9 determine the size of the lag screws from Table 4.25.

31. CROSS BRACING LOAD - Based on the entries in Lines 1, 9, and 15 and Table 4.27 calculate as follows: Load (lb.) = (Table 4.27 value x Ln 1) divided by (No. Ln 27 x 2). This value is used in Line 33.

32. BOLT CAPACITY - Based on the entries in Lines 15 and 23 choose a bolt diameter and corresponding capacity from Table 4.26.

33. NUMBER OF BOLTS PER CROSS BRACING CONNECTION - Calculate as follows: Line 31 divided by Line 32 and round up to the next whole number. Note that Line 33 can be recalculated by assuming a different bolt diameter and capacity in Line 32.

34. END BRACING LOAD - Based on the entries in Lines 2, 9, and 15 and Table 4.27, calculate as follows: Load (lb.) = (Table 4.27 value x Ln 2) divided by 2.

35. BOLT CAPACITY- Based on the entries in Lines 15 and 23 choose a bolt diameter and corresponding capacity from Table 4.26.

36. NUMBER OF BOLTS PER END BRACING CONNECTION - Calculate as follows: Line 34 divided by Line 35 and round up to the next whole number.

PART II

37. CLEARING - Determine if the manufactured home site must be cleared and the area ($ft.^2$) entered in Line 37. Obtain cost estimate for clearing ($\$/ft.^2$) and multiply times the area to be cleared to obtain total cost.

38. EXCAVATION - Determine if any areas on the manufactured home site must be excavated and the volume (cu.yd.) of earth to be removed entered in Line 38. Obtain a cost estimate for excavation ($\$/ft.^2$) and multiply times the volume to be excavated to obtain total cost.

39. EARTH FILL - Based on the desired volume of fill (cu.yd.) and cost estimate for fill ($/cu.yd.), determine the total cost for fill. Table 5.3 in Chapter V can be consulted as necessary.

40. SITE GRADING - If grading is necessary to prepare the manufactured home site, determine the volume (cu.yd.) and cost ($/cu.yd.) and multiply to obtain total cost.

41. ANCHORS - Based on the desired elevation and type of foundation design, determine the number of ground anchors required. Obtain the installed cost for ground anchors ($/anchor) and multiply times the number required to obtain total cost.

42. PIERS - The number of piers required is calculated as follows: [(Ln 1 ÷ Ln 4) +1] x 2. Based on the pier design chosen in Line 19, the required length of pier and need for additional bearing area, obtain a cost estimate for each pier ($/pier). Multiply the number of piers required by the cost per pier to obtain total cost. Note that wood cross bracing and bolt costs should be figured in Lines 46 and 50.

43. POSTS - The number of posts required is determined as discussed for piers in Line 42. Based on the post diameter chosen in Line 23, the required length in Line 21 and need for additional bearing area obtain a cost estimate for each post ($/post). Multiply the number of posts required by the cost per post to obtain total cost.

44. PILES - The total cost for piles is determined in the same manner as discussed for posts. Note, if a pile pull-out test is required, the cost should be entered as a miscellaneous cost in Line 56.

45. HORIZONTAL BEAMS - The total number of horizontal beams is determined as follows: No. Ln 26 x [(Ln 1 ÷ Ln 4) + 1]. Based on the size required from Line 26, a unit cost ($/beam) should be determined and multiplied by the total number of beams required to obtain total cost.

46. CROSS BRACING - The total number of cross bracing members is calculated as follows: No. Ln 27 x 2. Based on the size required from Line 27, a unit cost ($/member) should be determined and multiplied by the total number of members required to obtain total cost.

47. END BRACING - Based on the size required from Line 28, a unit cost ($/member) should be determined and multiplied by 4 to obtain total cost.

48. HORIZONTAL BEAM BOLTS - The total number of horizontal beam bolts is calculated as follows: (No. Ln 29 x No. Ln 43 or 44). Based on the size required from Line 29, a unit cost ($/bolt) should be determined and multiplied by the total number of posts/piles to obtain total cost.

49. I-BEAM LAG SCREWS - The total number of chassis I-beam lag screws is calculated as follows: (4 x No. Ln 43 or 44). Based on the size required from Line 30, a unit cost ($/lag screw) should be determined and multiplied by the total number of posts/piles to obtain total cost.

50. CROSS BRACING BOLTS - The total number of cross bracing bolts is calculated as follows: (No. Ln 33 x No. Ln 27 x 2). Based on the size required from Line 33, a unit cost ($/bolt) should be determined and multiplied by the total number of cross bracing bolts to obtain total cost.

51. END BRACING BOLTS - The total number of end bracing bolts is calculated as follows: (No. Ln 36 x 4). Based on the size required from Line 36, a unit cost ($/bolt) should be determined and multiplied by the total number of end bracing bolts to obtain total cost.

52. JACKING - Based on the manufactured home size, desired elevation above grade and foundation design, determine the total cost for jacking and placement of the manufactured home on the elevated foundation. Table 5.8 in Chapter V can be consulted as necessary.

53. UTILITIES - Determine any utility work which must be performed in conjunction with the elevated foundation design and obtain total cost.

54. STEPS - Based on the height above grade and number of exterior doors, determine the cost for exterior steps and landings.

55. SITE IMPROVEMENT - List any additional site improvements and their total cost.

56.-59. MISCELLANEOUS - List any additional items associated with the manufactured home installation not addressed in Lines 37 - 55.

60. TOTAL ESTIMATED MATERIAL COST - Add the total cost figures for Lines 37 - 59.

61. LABOR - Some of the items in Lines 37 - 59 may not include labor costs. For those line items, determine the man-hours required and multiply by the labor rate ($/hour) to obtain total labor cost.

62. TOTAL ESTIMATED COST - Add Lines 60 and 61.

PART III

Based on the information in Parts I and II, Figure F.2 can be completed to yield a drawing of the actual design. Where appropriate, spaces have been provided to enter dimensions and material descriptions.

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