Final Report

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INTRODUCTION

Jeff Gordon from the Building Research Council (BRC) at the University of Illinois Urbana-Champaign, and Robert Nemeth of Magna Systems, conducted a site visit at the Cherokee Nation on January 14-16, 2003. The purpose of the site visit was to provide technical assistance to the Cherokee Nation Housing Authority in assessing mold and moisture conditions in housing units. This is a summary report of activities and issues addressed while on site. A detailed analysis of the findings and recommendations is found in the attached reports, entitled: Technical Housing Assessment Report: Examining Mold and Moisture Conditions of Homes in Cherokee Nation Housing.

BACKGROUND INFORMATION

The Cherokee Nation covers 14 counties in northeastern Oklahoma. The region’s winter climate is generally temperate. The region has many lakes, streams, and rivers among rolling hills. The tribal lands, defined by the U. S. Census Bureau as a Tribal Jurisdictional Statistical Area (TJSA), are the second largest Native American community in the United States. Almost 100,000 Native Americans reside in the TJSA. The Housing Authority of the Cherokee Nation manages 1,716 Mutual Help homes, 973 Low Rent homes and 1,471 Section 8 Certificates. Mr. David Southerland, the Deputy Director of Housing for the Cherokee Nation, coordinated the site inspections.

Day 1: Tuesday, January 14, 2003

On Tuesday morning, the Assessment Team met with Cherokee Nation Housing Authority staff to discuss the day’s activities, outline the team’s role while on the reservation, and address the Tribe’s concerns regarding the site visit. Present at the meeting were David Southerland and two staff members from the Housing Authority’s building and maintenance staff, Jeff Gordon, Robert Nemeth, and Calvin Moser from HUD’s Eastern Woodland Native American Programs (E/WONAP).

David Southerland reported mold and moisture problems with some of the Cherokee housing units, but the extent of the problem is unknown.

After the meeting, the assessment team began the on-site inspections. Willard Oosahwee, Brian Mink, and Jeff Edwards of the Housing Authority’s building and maintenance staff, accompanied the inspection team on Tuesday’s inspections. Digital photographs were taken at each site to record conditions. The inspection process involved visual assessment of both interior and exterior conditions and discussion with available residents. Assessments were conducted on four homes and one vacant senior housing facility.
Day 2: Wednesday, January 15, 2003

On Wednesday three additional homes were inspected. Dean Gritts, a Project Inspector for the Cherokee Nation was the guide for the day. The attached *Technical Housing Assessment Report* provides a detailed analysis of findings and recommendations for the homes investigated.

Day 3: Wednesday, January 16, 2003

On Thursday morning Jeff Gordon from the BRC conducted a training session for the Cherokee Nation Housing and Maintenance staff. Items discussed included a background on what mold is, preliminary findings relating to mold and moisture problems, and potential causes for those problems, and mold remediation techniques. The sign-in sheet for this training session, Attachment 1, is found on page 26.

FINDINGS

An overview of findings for the Cherokee Nation housing site visit follows. Detailed discussions and recommendations on these findings are in the *Technical Housing Assessment Report*.

Cherokee Nation Housing

1. Exterior site drainage and rainwater management was a problem in most of the residences. Site drainage was rated poor or worse at six of the seven homes. Many of the sites were flat with no slope away from the foundation. In some cases, a hillside drained toward the building. All seven houses were missing roof drainage systems (gutters, downspouts, leaders, etc.), a condition that can place a tremendous moisture load on the foundation and the house.

2. In the three site-built houses with crawl spaces, the construction of the crawl spaces was substandard. There were no vapor barriers covering the soil in the crawl spaces. In some cases, the wet conditions were promoting mold growth. Some of the rot damage to the subfloors had created structural safety problems.

3. Three of the houses were suffering from mold growth as a result of winter moisture condensation. Mold growth from condensation sources was visible in bedroom closets, at the wall/ceiling juncture of exterior walls, and at the base of exterior walls.

4. Bathrooms and bathroom exhaust ventilation were significant issues found during the inspections of Cherokee housing. Operable exhaust fans were missing in six of the seven homes, including two of the homes with condensation problems.
5. Two of the inspected houses were subject to overcrowded conditions. Overcrowding multiplies the moisture generation from human sources, can contribute to elevated interior moisture loads, and ultimately (if other conditions are in place) lead to mold contamination from condensation problems. There was condensation and related mold contamination in both inspected houses with overcrowded conditions.

6. Of the seven inspected residential properties, only one property was heated by a central heating system. Heating method and heat distribution play vital roles in preventing wintertime mold and moisture problems. Additionally, the heating systems in the inspected houses presented other health and safety issues, including fire safety and exposure to carbon monoxide and other combustion byproducts.

7. Several maintenance issues contributed to mold and moisture conditions. Water entry through roof leaks, as well as plumbing leaks were evident in four of the seven houses.

PROGRAMMATRIC RECOMMENDATIONS

A particular challenge to all housing authorities is the development of a service-delivery system to effectively address mold and moisture conditions in a prompt fashion. This requires a partnership between the housing authority and occupants. A system should include training for the maintenance staff on topics to implement the technical recommendations and training for residents about their roles and responsibilities as renters and homeowners. In many cases, moisture problems develop but go unreported and unrepaired, allowing significant mold contamination that could have been avoided. Some strategies to remedy these problems follow:

1. Require attendance at annual homeowner/renter clinics as part of the annual recertification process. These clinics would provide instruction on home maintenance topics, such as identifying and repairing leaks or gutter maintenance.

2. During the annual recertification process, have occupants fill-out a survey based on Housing Quality Standards (HQS) and some additional questions on mold and moisture conditions in their homes. Having the resident complete the survey further engages the occupants in their own home maintenance. The survey responses would provide additional information to the housing authority on previously unreported problems (especially leaks and inoperable fans) that might contribute to an unsafe, unhealthy home environment.
TECHNICAL HOUSING ASSESSMENT REPORT

EXAMINING MOLD AND MOISTURE CONDITIONS IN HOMES OF THE OKLAHOMA CHEROKEE NATION

Executive Summary

Introduction

Section 1: Methodology

Section 2: Cherokee Nation Housing Types

Section 3: Findings

Section 4: Technical Discussion and Recommendations

Appendix A: Housing Survey Summary Form

Appendix B: Housing Assessment Results
EXECUTIVE SUMMARY

The site assessment team inspected seven homes of the Oklahoma Cherokee Nation for moisture and mold conditions. The seven principal findings derived from the inspections included:

1. Exterior site drainage and rainwater management was a problem in most of the residences. Site drainage was rated poor or worse at six of the seven homes. Many of the sites were flat with no slope away from the foundation. In some cases, a hillside drained toward the building. All seven houses were missing roof drainage systems (gutters, downspouts, leaders, etc.), a condition that can place a tremendous moisture load on the foundation and the house.

2. In the three site-built houses with crawl spaces, the construction of the crawl spaces was substandard. There were no vapor barriers covering the soil in the crawl spaces. In some cases, the wet conditions were promoting mold growth. Some of the rot damage to the subfloors had created structural safety problems.

3. Three of the houses were suffering from mold growth as a result of winter moisture condensation. Mold growth from condensation sources was visible in bedroom closets, at the wall/ceiling juncture of exterior walls, and at the base of exterior walls.

4. Bathrooms and bathroom exhaust ventilation were significant issues in the inspections of Cherokee housing. Operable exhaust fans were missing in six of the seven homes, including two of the homes with condensation problems.

5. Two of the inspected houses were subject to overcrowded conditions. Overcrowding multiplies the moisture generation from human sources, can contribute to elevated interior moisture loads, and ultimately (if other conditions are in place) lead to mold contamination from condensation problems. There was condensation and related mold contamination in both inspected houses with overcrowded conditions.

6. Of the seven inspected residential properties, only one property was heated by a central heating system. Heating method and heat distribution played vital roles in preventing wintertime mold and moisture problems. Additionally, the heating systems in the inspected houses presented other health and safety issues, including fire safety and exposure to carbon monoxide and other combustion byproducts.

7. Several maintenance issues contributed to mold and moisture conditions. Water entry through roof leaks, as well as plumbing leaks, were evident on four of the seven houses.

This report provides technical recommendations and discussions focusing on these items. Appendix A includes a summary of findings from the inspections. Appendix B provides a detailed assessment of each home.
INTRODUCTION

The assessment team responded to a request from the Southern Plains Office of Native American Programs to assess site and building structural conditions contributing to mold and moisture problems at the Cherokee Nation. Jeff Gordon, BRC staff, and Robert Nemeth, consultant from Magna Systems, conducted the investigations on January 14 and 15, 2003. Members of the housing authority maintenance staff and Calvin Moser from the ONAP Southern Plains Office of Native American Programs escorted the inspection teams.

The Cherokee Nation covers 14 counties in northeastern Oklahoma. The region’s winter climate is generally temperate. The region has many lakes, streams, and rivers among rolling hills. The tribal lands, defined by the U. S. Census Bureau as a Tribal Jurisdictional Statistical Area (TJSA), are the second largest Native American community in the United States. Almost 100,000 Native Americans reside in the TJSA. The Housing Authority of the Cherokee Nation manages 1,716 Mutual Help homes, 973 Low Rent homes and 1,471 Section 8 Certificates. Mr. David Sutherland coordinated the site inspections.

SECTION 1 - METHODOLOGY

Visual Inspection

Housing inspections consisted primarily of visual assessment of mold and moisture conditions. Assessment forms developed for the Chicago Mold and Moisture Project, a HUD Healthy Homes Program, were used to record information. The assessment forms were organized for a room-by-room inspection. All rooms were examined for water damage and evidence of mold. Assessment of kitchens, bathrooms, basements, crawl spaces, utility rooms and attics included additional inspection relating to plumbing, localized ventilation, water entry and other moisture source issues.

The exterior of the houses were inspected for rain water/snow melt management, including site grading, roof condition and gutter system.

Whenever possible, residents were interviewed to gather history on moisture problems, plumbing leaks, winter condensation, health issues, number of occupants and other useful information that could be offered.

Digital photographs were taken at each house to visually record notable conditions.

Measurements

Moisture content readings were taken in the baseboards of one residence. Due to the storage capacity of wood, moisture content measurements provide information on wetness in the recent past, from three weeks to a month. Moisture content readings can range from 5%, indication of a very dry reading, to 30%, indication of a very wet reading.
The results of the mold and moisture assessments were compiled on a spreadsheet, with broad categories of common moisture problems noted. This data is presented in Table 1 of the Appendix A in this report. The findings from each individual house inspection are presented in Appendix B.

SECTION 2 – CHEROKEE NATION HOUSING TYPES

The Housing Authority of the Cherokee is responsible for over 3,000 housing units in various programs. The assessment team examined seven housing units for mold and moisture. These seven units do not represent a typical cross-section of the units under their management, since were not based on a random sample. Three units were manufactured homes; the other four units were site-built homes.

The eight structure inspected was a former senior center which was not occupied.

Two of the manufactured homes were older, while the third had been installed two years prior. Three of the site-built homes were older wood-framed, wood-sided, ranch houses on crawl spaces. The fourth site-built home was a newer wood-framed, brick veneer ranch house on a concrete slab.

SECTION 3 – FINDINGS

There was visible mold growth in all seven of the houses inspected. In some cases, mold contamination was slight, generally limited to bathrooms. In other cases, mold contamination was extensive and acute throughout the house. Mold contamination is always associated with moisture problems. The following are seven general findings based on the inspection of the houses at the Cherokee Nation:

Exterior Site Drainage and Rainwater Management

This management is essential to maintaining dry foundations, and ultimately dry houses. Site drainage was rated poor or worse at six of the seven homes. Many of the sites were flat with no slope away from the foundation. In some cases, a hillside drained toward the building with no barrier or swale to divert water away from the foundation (Figure 1). Additionally, all seven houses were missing roof drainage systems (gutters, downspouts, leaders, etc.), a condition that can place a tremendous moisture load on the foundation and the house. All inspected crawlspaces were wet for these reasons. Section 4.1 discusses site drainage and rainwater management in more detail.
Crawl Spaces

The construction of the crawl spaces was substandard in the three site-built houses with crawl spaces (Figure 2). There was little depth to the space, making accessibility difficult. Some of the beams, piers, and other structural elements were undersized and poorly connected. There was a maze of nightmarish plumbing supply and drain lines. The crawl spaces were wet, primarily due to site drainage and rainwater problems, but also due to plumbing leaks. There were no vapor barriers covering the soil in the crawl spaces. In some cases, the wet conditions were promoting mold growth. Some of the rot damage to the subfloors had created structural safety problems. Wet crawl spaces are a leading source of excess moisture load in houses. Crawl space design and construction is discussed in Section 4.2.

Winter Moisture Condensation

Three of the houses suffered from mold growth as a result of winter moisture condensation. Mold growth from condensation sources was visible in bedroom closets, at the wall/ceiling juncture of exterior walls, and at the base of exterior walls (Figure 3). Condensation occurs when moisture-laden air comes in contact with a building surface that is chilled below the dew point of the air. This problem indicates a combination of two factors:

- A house with a high wintertime moisture load (relative humidity), and
- Areas of the building that are below the desired interior temperature.

Lowering the moisture load and/or insulating or heating surfaces to prevent cold surface temperatures can treat the problem. Section 4.3 discusses condensation issues. The following three findings are also related to the condensation problem.
Bathrooms and Bathroom Exhaust Ventilation

These were significant issues in the inspections of Cherokee housing. Bathrooms, by the nature of their function, are common rooms for the development of localized mold problems. Plumbing problems, both past and present, were identified in three houses (Figure 4). Lack of cleaning and maintenance had caused mold problems in bathrooms of two houses (Figures 5 and 6).

Bathroom ventilation can play an important role in reducing interior moisture load. Operable exhaust fans were missing in six of the seven homes, including two of the homes with condensation problems. Bathrooms and localized exhaust ventilation is discussed in Section 4.4.

Overcrowded Conditions

Two of the inspected houses were subject to overcrowded conditions. Overcrowding multiplies the moisture generation from human sources, can contribute to elevated interior moisture loads, and ultimately (if other conditions are in place) lead to mold contamination from condensation problems. There was condensation and related mold contamination in both inspected houses with overcrowded conditions. One case had nine residents in a small ranch house. The other case had six residents in a mobile home. Discussion of human moisture sources can be found in Section 4.5. Inspection 1-4 of Appendix B also presents a case study discussion of this problem.

Heating Method and Heat Distribution

Of the seven inspected residential properties, only one property was being
heated by a central heating system. The other houses were being heated by a single heat source in one room, either a propane heater (Figure 7), wood stove (Figure 8), or, in one case, an electric oven. Heating method and heat distribution plays a vital role in preventing wintertime mold and moisture problems.

Additionally, the heating systems in the inspected houses presented other health and safety issues, including fire safety and exposure to carbon monoxide and other combustion byproducts. Heating systems are discussed in Section 4.6.

**Maintenance Issues**

Several maintenance issues contributed to mold and moisture conditions.

- Water entry through roof leaks was evident on four of the seven houses. Both active (still leaking) and inactive water entry was noted. Roof leaks can result in acute structural damage and mold contamination.

- Plumbing leaks were identified in four of the seven houses. Two cases featured leaks in the water supply; the other two cases featured leaks in drain lines. Maintaining plumbing in proper working order is a high priority maintenance item. Lingering plumbing leaks that persist for months and even years can lead to severe structural damage and mold problems.

- General cleanliness and clutter was a problem in many of the houses. This issue is primarily the responsibility of occupants. Cleanliness is critical in bathrooms and other wet areas, where regular maintenance cleaning can keep mold conditions under control. The presence of clutter in closets and on exterior walls can contribute to mold growth and condensation problems when sufficient moisture is present. Maintenance issues are discussed in Section 4.7.

**SECTION 4 - TECHNICAL DISCUSSIONS AND RECOMMENDATIONS**

The following discussions and recommendations are based on the seven general findings identified during the site visit to the Oklahoma Cherokee Nation.

**4.1 Site Drainage and Rainwater Management**

**Site Drainage**

When rain falls on a building site, where should the water go? The roof should be designed and built so that the water that lands on the roof is moved out to the edge of the
roof. When rain falls on a soil surface, some of it will percolate downward through the soil—more in sandy soils and less in clayey soils. The water that does not percolate downward will move along the soil surface following the slope, out to the downhill edge of the site. The best way to prevent mold and moisture problems in houses is to make sure that rainwater moves off the roof, across the site and off the property. The houses with problems are those that allow water to accumulate in the soil that is in contact with the foundation. In a well-managed property, the soil that is in contact with the foundation should be the driest soil on the site following a rainstorm. Houses with dry foundations (basements, crawl spaces and slabs) are usually dry houses. Keeping the foundation dry is the key to a good indoor environment in most houses. To keep the foundation dry, keep the soil dry that is next to the foundation.

Keeping the soil that touches the foundation dry involves two general rules, together with some specific guidelines.

The first general rule is concentration - damage is worse where greater quantities of water are concentrated. A valley on a roof acts like a funnel, with the greatest concentration of water at the base of the valley. Gutters also act like funnels that collect water from the edge of the roof and concentrate it in the downspout. On the land, valleys and swales act like collectors or funnels that concentrate the water on the site. If the water management design makes use of funnels (such as valleys, gutters or swales) then they require maintenance to make sure they work as intended. Damage is worst where a valley, gutter or swale is blocked.

The second general rule is the ground roof rule - treat the soil surface as if it were a low-slope roof surface. Pitch the surface away from the house - the steeper the pitch, the better the drainage. Imagine all the water moving to the low edge of the site, and imagine how best to get it there. Avoid areas near the building that can act as water collectors.

Specific site drainage guidelines include:

- The house should be built on a crown, not in a hole. If there is sufficient exposed foundation, site grading at the house can be improved. If the house hugs the ground, improvements at the foundation are more difficult. There should be a minimum of eight inches of exposed foundation between the ground and the beginning of the siding.

- Identify localized dips and holes immediately adjacent to the foundation, fill with dirt, and tamp the fill material to prevent future settling. Provide sufficient fill material such that drainage occurs away from the foundation.

- If the house has no gutters, then the base of the soil around the house has to serve as a gutter. It should have a surface that helps prevent splash back onto the siding of the house and should be designed with pitch so that it effectively moves water away from the house.
- Good tamping or compaction of the backfill is very helpful because it helps keep water on the surface where it can be managed by slope. Soil at the outside corners of the foundation, where the downspouts are usually found, can always be tamped because the corner will not collapse inward.

- Bushes and other plantings may be very helpful, especially if their root balls soak up a lot of water. Also they can be planted strategically near downspouts so that the downspout extenders are less likely to be kicked off or removed during lawn mowing.

**Rain Water Management**

Rain water and snow melt from the roof should be collected and distributed away from the foundation with a gutter system. Flashings around chimneys and vents should be watertight.

- Include waterproofing underlayment at the eaves and in valleys as part of re-roofing to help prevent water damage caused by ice dams.

- As part of a management system, pitch the gutters to the downspout. Short gutters may be hung level. In hip roof houses, consider using downspouts only on the downhill side not on the uphill side. In areas with a moderate amount of trees, consider large gutters and downspouts where hangers are solid so that they keep the gutter from sagging.

- Downspouts should be secured to the house. They should never be undersized, and some oversizing never hurts. Fasten elbows and straight sections together with pop rivets—screws that project into the downspout can lead to clogging.

- At the base of the downspout, the water has to be directed away from the foundation of the building (Figure 9). It should be directed out past the backfill onto the undisturbed soil, which may be 3' to 5' out from the edge of the house. If
it is allowed to dump water close to the foundation, into the backfill, it will concentrate the water next to the foundation—precisely the wrong place for the water to be. The traditional way to discharge the water away from the house involves using downspout extenders (sections of straight downspout) or splash blocks. Both of these are often disturbed when lawns get mowed. Instead, use a notched section of downspout that is hinged to the elbow at the base of the downspout. The soil at the base of the downspout should be sloped away from the house at a minimum of 5% slope. Six inches of fall in the first 10’ away from the house gives a 5% slope.

- Keeping cutters clean in wooded areas can be a maintenance issue. A gutter guard system can help keep debris out of the gutter, thus minimizing maintenance, while allowing water to drain into the gutter.

An example of a gutter guard system is the *PermFlow Gutter Guard System* (Figure 10). This system costs about $4.50 per 3’ section and is designed for a 5” K style gutter (8’ sections are sold to contractors). Similar systems such as the *Waterfall Gutter Guard* are available (Figure 11).

**Figure 10: PermFlow Gutter Guard System**

**Figure 11: Waterfall Gutter Guard**

4.1 Crawl Space Design

Moisture entry and evaporation from foundation sources are major contributors to the moisture load in a house. Because they are rarely visited or inspected and problems go unaddressed, crawl spaces are particularly notorious for leading to foundation moisture problems. When moisture entry is acute, framing and subflooring can deteriorate and support mold. The following points relate to crawl spaces in general, regardless of thermal boundary.

- Crawl spaces should have easy access and good lighting so as to enable regular inspections. There should be sufficient headroom to allow for reasonable ease of movement and ability to perform repairs and improvements.
- Water in crawl spaces typically comes from poor rainwater management outdoors, plumbing leaks, air conditioner condensate or water softener discharge. Rainwater management is by far the leading source of water in crawl spaces.
• Crawl spaces should be covered with a ground material: a slab of concrete, a polyethylene sheet or other vapor-proof material. The ground cover must be sealed to the foundation walls. All joints and seams must also be sealed. The ground cover must also be sealed to foundation piers interior to the crawl space.

• Crawl spaces should be insulated. There are two ways to insulate a crawl space, depending on where the thermal boundary is to be established. The thermal boundary is the building section that separates conditioned space from outside conditions. Insulation can either be placed on the crawl space walls (placing the crawl space inside the thermal boundary) or in the floor of the house (placing the crawl space outside the thermal boundary). If the crawl space contains mechanical systems (plumbing, ductwork), the space should be inside the thermal boundary.

The crawl spaces in the inspected Cherokee housing violated all of these points. All the crawl spaces were uninsulated and had no vapor barriers in place. The crawl spaces were wet from poor rainwater management. More critically, all the crawl spaces had very low clearance and access, making improvements difficult to accomplish. Improving the headroom and access in an existing crawl space is not very practical. At the very least, existing crawl spaces should have a vapor barrier installed, and rainwater management improvements made to the exterior through site grading and roof drainage systems.

The following discussion on new crawl space design is provided to clarify principles, and to serve as a guide for future construction.

A clear distinction should be made whether the crawl space walls or the floor above the crawl space is the thermal boundary for a home. Insulation on the foundation walls indicates that the foundation walls form the thermal boundary, and that the crawl space is part of the conditioned space. In this case, it is not desirable to provide crawl space ventilation which is analogous to opening a window in a heated room. If insulation is placed in the floor above the crawl space, then the floor is the thermal boundary, and ventilation can be installed. Mechanicals (plumbing, ductwork) should be inside the thermal boundary in all cases.

• **Crawl Space Walls Are the Thermal Boundary**

The crawl space is unvented. It shows an exterior insulation system that allows a shallower frost wall, although the foundation wall may be insulated in down to the footing, either on the inside or outside of the foundation wall. The drawing also shows a concrete pad sloped to a sump pump. Should water get into the crawl space, it can be drained and pumped from the crawl space. The concrete pad serves as a ground cover that can be cleaned and is more durable than a polyethylene ground cover.
In essence, the crawl space is designed as a stubby basement that is conditioned as a result of ductwork, and in some cases, furnaces being located there. As unvented crawl spaces are not yet allowed by most codes, it may be necessary to add closeable vents to obtain a building permit.

- **Floor Above the Crawl Space is the Thermal Boundary** (Figure 13, below)

This detail shows a well-vented crawl space. The bellyboard membrane seals the home from the crawl space. A small drain to discharge any leaks or overflows from the bathroom and kitchen may be added. No ductwork or piping should be at floor run in the crawl space, except for services.

Water service piping should be insulated with...
electric heating tape. Generous venting is required in the foundation walls, with the vents held well off the ground. Vents installed according to code can only deal with small amounts of moisture. Consequently, it is essential to include a continuous and sealed ground cover to ensure that water drains away from the crawl space.

4.2 Winter Condensation Problems

Condensation occurs when moisture-laden air comes in contact with a building surface that is chilled below the dew point of the air. When this happens, the moisture content of the materials at the location increases, potentially up to saturation, and mold grows on the surfaces. This problem indicates a combination of two factors:

1. A house with a high wintertime moisture load (relative humidity), and
2. Areas of the building that are below the desired interior temperature.

In cases where this problem occurs two approaches address the problem:

1. Identify the moisture sources that contribute to the elevated humidity in the house and reduce or eliminate these moisture sources, and
2. Identify the cause of the chilled surface and add insulation or airflow improvements to reduce or eliminate the chilling of the surface.

Identifying and reducing moisture sources to lower relative humidity in the winter is always the first step. Moisture sources can include:

- Foundation moisture sources – wet basements and crawl spaces
- Bathroom moisture sources due to lack of localized ventilation
- Human moisture sources which result from overcrowding.

All three of these sources were identified in the Cherokee houses that were experiencing condensation problems. As can be seen from this list, the problem is related to other issues discussed individually in the report, including site drainage and rainwater management (Section 4.1.), crawl space design (Section 4.2.), bathrooms (Section 4.4.), and overcrowding (Section 4.5.). Minimizing these moisture sources is discussed in the respective sections.

In some cases, particularly in those cases involving overcrowding in weather-tight houses, adding whole house ventilation can reduce the moisture load in the house. Ventilation should be considered after all of the other moisture sources have been addressed.
Maintaining surface temperatures above the dew point temperature is the second approach. Moisture source control should always be considered first, because the lower the relative humidity, the lower the temperature that is tolerable. The problem can occur, however, at a reasonable interior humidity if there is a specific construction flaw that allows a surface to get chilled in the winter.

A problem in the inspected Cherokee housing relates to the problem of surface temperatures. A simple approach to heating in the homes, involving a single point source for heat rather than central heating, contributes to chilled surface temperatures in rooms that are distant from the heating source. Cold rooms can lead to condensation problems and mold growth. This issue is discussed in Section 4.6.

A common condition leading to winter condensation and mold problems occurs in closets on an exterior wall (Figure 14). The design and use of closets conspire to make this condition common, specifically:

- Lack of heat supplied to closets and closed closet doors
- Lack of airflow in closets, which would distribute heat to the closet exterior surface
- Closet clutter that prevents airflow and heat to reach the closet exterior wall
- Clothes hanging against the wall, which act as insulation and lower the temperature of the wall

Again, a relatively cold room contributes to this problem. Preventing this mold condition requires ensuring that the exterior wall of the closet does not get chilled. Closets should not be cluttered, and residents should maintain some distance between the clothes and the exterior wall. Closet doors should be louvered and the room kept at a decent temperature. Exterior walls should be insulated. Again, the moisture load in the house should be kept at a minimum.

Another location that commonly experiences chilling and subsequent condensation and mold contamination is at the wall/ceiling juncture on exterior walls. This is a very common problem in northern climates in older ranch-style homes.
with low-pitched roofs. This problem was identified in Cherokee housing, as well (Figure 15).

There are at least three reasons why the exterior wall/ceiling juncture gets cold:

1. Cold wind may enter through soffit vents and pass through the porous insulation material, degrading its thermal performance.

2. The insulation may have been poorly installed resulting in reduced amounts of insulation in the corner.

3. The geometry of the corner usually means that slow-moving currents of warm air may not be able to reach into the corners (Figure 16).

Dark spots occur where the interior surfaces are the coldest because that is the hardest place to insulate effectively. In new construction, use a raised-heel truss and make sure the insulation installer pays special attention to the wall-roof joint. Anyone who has tried to insulate an attic knows that it is difficult to carefully insulate the exterior edge of the attic, especially in homes with low-pitch roofs. With batt insulation, special pusher sticks may be used to get the insulation out to the edge. With

1. Wind through soffit vents chill the corner

2. Inadequate insulation over the corner

3. Indoor currents of warm air do not enter into corners.

Figure 16: Wall-ceiling corners are cold because of 1. Wind movement through soffit vents, 2. smaller amounts of insulation at the corner and, 3. corner is outside the movement of warm air currents indoors.

Insulation pushed up against baffle
New cellulose insulation as air block
Attic vent baffle
New rigid foam, sealed with spray-applied foam.

Figure 17: Insulation retrofit for the juncture between the exterior wall and the roof-ceiling assembly. Note that this retrofit is done from the outside.
loose fill insulation, the outside edge should be prepared correctly so that it is packed with insulation.

In existing construction consider using a retrofit as shown in Figure 17. The work is done from the outside. Remove the soffit material. Install a fiberglass baffle in each cavity space. Push the existing insulation back up against the sheathing or the baffle. Blow in new cellulose insulation, or pack in fiberglass insulation, into the cavity. Then install pre-cut rectangles of rigid foam insulation to block air flow. If blowing in loose-fill insulation, the rigid foam insulation should be installed first, and blown insulation second. Use spray-applied foam insulation to keep the rigid rectangle in place. Replace the soffit. If the attic is ventilated, make sure that nothing blocks the baffles.

Many individuals and organizations (including model codes) stress the importance of attic ventilation. While it has some benefits, it also has some drawbacks. Wind washing of insulation at the edge is one of the major drawbacks. Designs without attic ventilation may improve the performance of the eave area, and most designs without ventilation rely upon the verified airtight ceiling plane for good moisture performance. For more information about the benefits and drawbacks of attic ventilation see “Issues Related to the Venting of Attics and Cathedral Ceilings” at http://www.fpl.fs.fed.us/documnts/pdf1999/tenwo99a.pdf.

The retrofit presented is designed to keep the wall/ceiling juncture warm, and eliminate the condensation site. Lowering the moisture load in the house and reducing the relative humidity, also helps prevent wintertime mold and moisture problems.

4.4 Bathroom Mold Problems

Bathrooms are the sites of many mold and moisture problems in homes. This is normal, because they are the wet test rooms in the house. Keeping bathrooms dry depends on care in several areas:

Bathroom plumbing should not leak. There should be no leaks, in either the water supply system or the drain-waste-vent (DWV) system. All plumbing leaks should be fixed promptly. Some leaks may be hard to detect, such as a leak at the toilet flange or a leak at a shower drain.

Users of bathrooms should be careful. Shower curtains should be used in a way that all the shower water goes into the tub; none of it escapes out at the front of the tub. Toilet users should be careful. Surfaces in the bathroom should be selected and installed to keep water away from drywall and other materials that may permit mold to grow. Any spills should be cleaned up promptly. Dirty and discolored spots should be cleaned. Any water problems that may have led to the spotting should be corrected. Damaged drywall should be removed and replaced. Keeping surfaces clean and dry is primarily the responsibility of the residents of a house.
Bathrooms are one of several rooms in a house that are naturally moisture sources simply by the nature of their function. Showers are taken in bathrooms resulting in 100% humidity in that room. Kitchens are used for cooking and cleaning. In laundries, clothes dryers must remove large quantities of water from wet clothes. By removing moisture at the source in these areas, exhaust ventilation serves as a source control strategy for reducing the moisture load in a house. Exhaust ventilation dilutes the moisture and places the room in a negative pressure, thus limiting the spread of moisture to the rest of the house until most of the moisture has been removed to the outside.

Bathroom exhaust fans, kitchen exhaust fans and clothes dryers should always vent to the outside rather than into the living space. Venting to the basement, crawl space and attic can lead to moisture problems occurring in these areas. For this reason, localized exhaust ventilation requires ductwork. If the vent discharges through the roof, make sure the vent has an effective check valve to prevent wind blowing back through the vent. The vent may discharge out at the soffit area, but the vent duct should penetrate through the soffit panels and terminate in a grille.

Bathroom exhaust fans should exhaust between 50 cubic feet per minute (CFM) and 70 CFM. The effectiveness of exhaust fans is based on the power of the exhaust fan, length and type of exhaust duct and cleanliness of the fan grille. When there is excessive resistance in the ductwork, the exhaust fan motor may not be powerful enough to vent sufficient airflow through the duct. The longer the duct length, the greater the static pressure in the duct and the less air flow through the duct. Turns and bends in the ductwork also increase the static pressure and reduce flow. Similarly, a smooth duct provides less resistance and improved flow over ribbed ductwork. For all types of exhaust ventilation, using round, smooth sheet metal ductwork is recommended. Generally, the larger the duct, with the fewest bends or elbows, and the shortest duct run, is preferred. A dirty intake grille will also greatly increase resistance and reduce airflow.

Noisy exhaust fans are not likely to be used, so exhaust fans with a low “sone” rating should be selected. To ensure they get used, consider:

- Exhaust fan hard-wired to the bathroom light, and/or
- Exhaust fan on a timer, to extend moisture dilution time following a shower.

A good combination control features both of these approaches, where the fan is hard-wired to the light, but also runs for a programmed period following bathroom use. (Available from Energy Federation Incorporated, www.efi.org, Fan/Light Time Delay Switch). Residents should be encouraged to always use the bathroom exhaust vent.

4.5 Human Moisture Sources

Human occupation naturally produces moisture in buildings. Humans are similar to internal combustion engines, and respiration, the act of breathing, produces considerable moisture. Other human activities and preferences also produce moisture:
• Showering
• Cooking
• Cleaning
• Drying laundry
• Accidental spills
• House plants
• Firewood storage
• The use of humidifiers and vaporizers

All of these moisture-producing activities contribute to the moisture load in a house.

Generally, human moisture sources alone will not produce enough moisture to cause winter condensation and mold problems in the winter. However, there are two circumstances when the human moisture sources may result in problems:

1. Overcrowding. When the number of residents living in a house is clearly excessive for the size of the house, the moisture burden increases. Each person is participating in the moisture-producing activities (breathing, cooking, washing, etc.). If the number of people for the capacity of a house doubles, the moisture load from human sources also doubles.

2. Weather-tight construction. In the absence of a mechanical ventilation system, natural infiltration (air leakage) is the source of fresh air in homes during the winter. It is this fresh, dry, winter air that dilutes the moisture in the interior air and helps keep relative humidity under control. The amount of infiltration (the air change rate) that occurs in a house varies depending on the house. Some houses are naturally leaky, while others are more airtight. A particularly tight house may exhibit high relative humidity in the winter, which could lead to moisture and mold problems.

When these two conditions are present in the same house, that is, when a house is overcrowded and exhibits a low air change rate, an excessive moisture load can occur and maximize the potential for localized condensation and mold growth.

If winter condensation problems occur in a crowded house, all other sources of moisture should be identified and minimized. If the problem persists, then the house should be tested for its relative tightness or leakiness. This is accomplished with a blower door test. Agencies responsible for performing low-income weatherization usually have the equipment and expertise to perform this test, and can confirm whether the air change is too low for the size of a house and its number of residents. If this proves to be the case, then consideration should be given to providing additional ventilation for the house and residents. This can be accomplished in any number of ways. Installing a good bathroom exhaust fan on a humidistat control might accomplish the goal. If the house has a central forced air heating system, then the existing fan and ductwork can be augmented with a connecting duct to the exterior, and controls added to provide fresh air circulation. The
services of a mechanical engineer with some experience in residential ventilation systems would be valuable when addressing a problem of this kind.

4.6 Heating Systems and Moisture Control

The obvious purpose of heating systems during the winter is to provide comfort for the occupants. Heating systems can also impact winter moisture problems in several ways. Two of the critical ways are as follows:

1. The heating system is a major determinant of the temperature of interior surfaces. If heat is inadequate or poorly distributed, some wall and ceiling surfaces may be chilled near or below the dew point temperature leading to condensation problems. Occupants play a role in this if they close off rooms, cover supply ducts, block airflow to exterior walls, or adjust the thermostat down.

2. With the exception of electric heat, most heating systems depend on combustion of fuels. A major byproduct of combustion is water vapor. If a combustion appliance is improperly vented, or not vented at all, then the heating system can contribute enormous amounts of moisture into the interior air.

With regard to the first issue, central heating systems are preferred over stationary, single source heating systems (propane space heaters, wood stoves). Central heating systems feature ductwork that supply heated air (or heated water to radiators in hydronic systems) to all of the major living spaces of the house. If the heating plant and distribution system are properly designed and functioning, this serves to keep all of the rooms warm, and minimizes the potential for chilled surfaces throughout the house. Chilled surfaces are potential condensation and mold contamination sites.

If a house uses a single, stationary heat source like a wood stove or propane heater, the heat distribution in the house is dramatically affected. The room with the heating appliance will be warm (and even hot) while the rooms at the furthest distance from the heat source will be cold. The potential for chilled surfaces and mold problems rises dramatically in the cold rooms. The areas of greatest potential for condensation problems are in closets on exterior walls, and at the wall/ceiling junction on exterior walls. If the rooms are particularly cold and the indoor relative humidity is high, condensation can occur most anywhere on exterior walls and ceilings.

With regard to the second issue, any appliance that burns a fuel, be it gas, fuel oil, or wood, produces moisture. Generally, for every molecule of fuel consumed, two molecules of water vapor are produced. If the combustion gases are not well ventilated to the outside of a home, the appliance can contribute large quantities of moisture into the indoor air. The excessive moisture load in the air can be a major contributor to winter moisture problems.

In the inspected Cherokee housing, only one home was centrally heated. Three homes were heated with a stationary propane heater, two with wood stoves, and one with an
electric oven (though formerly with a wood stove). Generally, there was a casual approach to winter heating that is not the case of housing in colder climates. The condensation and mold problems in two of the houses were certainly impacted by the lack of central heat, as the mold conditions were occurring in bedrooms away from the heat source. Central heating would help address these problems.

There are, no doubt, economic reasons for the choice of heating systems. Low-income residents may prefer the slight discomfort of lower bedroom temperatures to the cost of central heating. While central heating would be preferred, the cost and difficulty of retrofitting a system, along with resident preference, may dictate against this solution. In those cases, every effort should be made to maximize the distribution of heat from the central appliance.

- Doors to all rooms should be left open. Rooms that are shut off contribute to the problem.
- Where possible, “through-the-wall” fans can be installed from the room with the heat source (typically the living room) to adjacent rooms. These fans can be installed with variable speed controls, and can distribute heat at a nominal cost.

Of equal importance is the ventilation of stationary combustion appliances. Two of the three wall-mounted propane heaters inspected were not vented. The effectiveness of the ventilation of the inspected wood stoves was questionable. As was previously stated, unvented appliances will contribute enormous amounts of water vapor into the indoor air.

Moisture problems, however, are only one issue relating to unvented and improperly vented combustion appliances. Combustion produces other contaminants, most critically carbon monoxide (CO). Carbon monoxide is a colorless, odorless gas that is poisonous. At high concentrations, carbon monoxide is lethal. Over 600 people a year die from accidental carbon monoxide poisoning in the United States. Even a well-tuned combustion appliance produces some CO, and a poorly tuned appliance can produce large quantities of CO. Combustion also produces nitrogen dioxide and particulates that can be irritating.

Unvented combustion appliances should not be tolerated. All combustion appliances should be properly vented. Building codes are strong on this issue. Whether a building code applies to Cherokee housing or not, code guidelines should be followed regarding the venting of combustion appliances.

Other safety issues were associated with the wood-burning stoves that were in use. In one case, a wood-burning stove was installed directly over the living room carpet without fireproof protection on the floor. Again, building codes related to fire protection in homes are very strong. Code guidelines should be followed regarding the installation, clearances, and vent penetrations that are critical to fire safety of wood stoves and other combustion appliances. In several cases during the mold and moisture inspections, it was
observed that, while mold may be present, risks to occupant health and safety were much greater from combustion and fire.

4.7 Maintenance Issues

Many moisture problems, and consequent mold contamination, result from deferred maintenance. If water infiltration problems from plumbing, roofing, or foundation sources linger, a small problem can turn into a large problem. A minor problem with a small potential for mold can turn into a major contamination site. Unfortunately water leakages often go unreported and unattended. Roof and plumbing leaks should be attended to promptly.

A housing authority’s best defense against mold and moisture complaints is its maintenance department. A good proactive maintenance program guards against mold and moisture problems by including the following procedures:

- Perform regular inspections of properties to identify problem moisture conditions
- Encourage reporting of moisture problems from residents
- Respond promptly to identified and reported moisture problems to prevent excessive mold contamination

Clearly, a prompt response implies a partnership between tenants and the housing authority. Residents must promptly report mold and moisture problems, and maintenance staff must promptly respond to the residents’ reports. If either party defers in their responsibility, the list of deferred maintenance items will grow, and small moisture and mold problems will turn into major problems with possibly severe mold contamination. Maintenance staff should be trained in the following items to assist in solving and eliminating moisture and mold problems.

General

- What is mold
- What causes mold
- Other Indoor Air Quality (IAQ) problems
- Sources of moisture
- Moisture assessment procedures

Exterior

- Site drainage
- Maintenance of roof drainage systems (gutters, downspouts, etc.)
- Paving adjacent to homes
- Repair of roofs and roof flashings
Foundations

- Crawl space design issues
- Sump pumps

Attics

- Attic bypasses
- Attic hatches
- Attic ventilation
- Insulation
- Wall/ceiling junctures

Mechanical

- Bathroom and kitchen exhaust fans
- Venting exhaust fans to the exterior
- Plumbing leaks
- Humidifiers
- Unvented appliances

Mold Remediation

- Clean-up
- When to call for outside help

At the same time occupants should be aware of their crucial role in preventing mold and moisture problems. A number of occupant issues bear directly on the causes and severity of moisture and mold problems. Occupants should receive training on the following topics to assist in solving and eliminating moisture and mold problems in their homes.

- What is mold and what causes it
- Use of exhaust fans
- Regular bathroom cleaning
- Avoidance of clutter in critical locations (exterior walls of closets, etc.)
- General housekeeping
- Use of crawl spaces
- Gutter and downspout maintenance
- Difference between plumbing leaks and water condensing on pipes
- Use of sump pumps
- Humidifiers
1/18/2003

ATTACHMENTS

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Hapla, OJ

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DEAN GRITTS

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ROGER CUNNINGHAM
DAN KELLEY

TOM KELLEY

NEIL TEAGUE
JEFF JACKSON

JEFF EDWARDS

DAVID TURNER

JANET KENN

BRAD PUNT

STEVE LEWIS

FLIGHT CORD

GEORGE HUBBARD

DAVID SUTHERLAND

ELTON ODE
## Summary Table of Home Assessments

<table>
<thead>
<tr>
<th>Inspection Number</th>
<th>Address</th>
<th>Building Age (Years)</th>
<th>Occupancy</th>
<th>Model Type</th>
<th>Foundation Type</th>
<th>Framing Type</th>
<th>Heat Type</th>
<th>Basement Framing moisture content</th>
<th>Site Drainage Problems</th>
<th>Gutter System Problems</th>
<th>Leaks From Exterior</th>
<th>Wet Basement or Crawl Space Problems</th>
<th>Plumbing Problems</th>
<th>Bathroom Problems</th>
<th>Exhaust Ventilation</th>
<th>Exterior wall/ceiling problems</th>
<th>Attic Problems</th>
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</table>
Address: 210 E. Sequoia
Model Type: Mobile Home
Age: Old
Bedrooms: 2
Foundation: Piers w/skirting
Heat Type: Unvented Propane
Construction: Wood frame/metal siding
Attic: Closed Assembly

Mold and Moisture Conditions: A severe mold and moisture problem had developed as a result of a leak in the supply line to the toilet. There were several water spots on ceiling from prior roof leaks, which did not appear active at the time of inspection (Figure 2).

Rainwater Management: There were minimal gutters and no overhang to the roof of the home. The site was flat with no clear path for the removal of rainwater.

Foundation Conditions: The skirting around the base of the home was not removed. Areas of the skirting had surface rust.

Bathroom: According to the residents, a leak in the supply line to the toilet had occurred and persisted for some period of time, leading to damage to the bathroom floor, the adjacent bedroom floor, and the wall between the two rooms. The damage to the bedroom floor had resulted in structural voids that were obvious through the carpet. The water damage had also affected an electrical outlet in the wall, which the residents had sealed off due to safety concerns (Figure 3). While the leak had been repaired, the structural damage to the floors, the cosmetic damage to the walls, and any associated mold, had not been addressed. There was no bath fan.

Attic: The attic assembly was not accessible, but there was evidence of roof leaks in several locations, as shown by water stains on the ceilings (Figure 2).

Mechanical Systems: There was no active central heating system in the house, which was being heated with an unvented propane wall appliance (Figure 4). Unvented combustion appliances present potentially serious indoor air quality issues due to the emission of combustion gases,
particularly carbon monoxide. Combustion could also generate large quantities of water vapor.

**Occupant Issues:** There were three occupants in the home. One of the occupants mentioned having health problems while the plumbing leaks were occurring, but did not elaborate as to the type of problems.

**Discussion / Recommendations:** The mobile home was in such poor condition that consideration toward replacement, rather than repair, should be investigated before investing in the house.

The moisture source (plumbing leak) leading to the mold problem has been addressed. Repairs and mold cleanup are still required, specifically:

- Remove the drywall from the wall behind the bathroom toilet. Make repairs and cleanup any leftover mold in the wall cavity. Repair electrical wall receptacle.

- Remove carpeting from the bedroom. Make structural repairs to floor and cleanup mold as required.

Additionally, the roof will require regular inspection and maintenance to prevent leaks and subsequent mold and moisture damage. Consideration should be given to providing a ventilated heating system that would not subject residents to combustion byproducts during the heating season.
Inspection Number: 1-2  
Address: Old Highway 64  
Model Type: Mobile Home  
Age: Old  
Bedrooms: 2  
Foundation: Piers w/skirting  
Heat Type: Wood Stove  
Construction: Wood frame/metal siding  
Attic: Closed Assembly

Mold and Moisture Conditions: Roof leaks have caused water spotting and some mold contamination on the ceilings of the house.

Rainwater Management: There were no gutters or overhang. The site was flat with no clear path for the removal of rainwater. The entry had a piece of flashing above to divert rainwater away from the entry (Figure 2).

Foundation Conditions: The base of the mobile home had skirting around part of the structure, with the rest left open to the environment. The soil below the structure was damp. The space was providing shelter for numerous dogs living on the property.

Bathroom: Extensive mold growth appeared inside the shower stall at the base of the unit (Figure 3). This contamination resulted from a lack of maintenance and regular cleaning, rather than a building defect. A roof leak above the bathroom had created considerable damage, with a sizable portion of the ceiling having collapsed (Figure 4). There was no bathroom exhaust fan.

Attic: The roof assembly was not accessible. There was evidence of roof leaks in several locations, but the extent of mold growth in the attic space could not be determined (Figures 5 & 6).
Heating System: The primary heating system consisted of a wood stove in the living room placed directly on the carpeted floor of the home, rather than on a fireproof floor covering. The side door of the stove was open and ashes were present (Figure 7). The stove was vented out the back and through an existing window that had been replaced with a piece of corrugated metal (Figure 8). The stovepipe itself appeared to be a single-wall pipe and terminated above the mobile home in a ninety-degree bend (Figure 9). The arrangement of the wood stove and its method of venting presented fire hazards.

Electrical System: The entire mobile home’s service and wiring was dubious. The service entrance was a rubberized cable coming from a power-pole behind the home (Figure 10). The water heater was fed through what appeared to be 12 gauge wires on 30 amp fuses and was regularly disconnected, when not in use, so as to not overload the service. The service to the well also fed off the power pole and was strung overhead behind the home and secured to a tree before going into the well. One of the outlets in the back bedroom had experienced a short and half of the duplex receptacle appeared to be melted plastic, unusable or at best, dangerous to use.

Kitchen Facilities: Due to electrical problems, the residents reported that many of the electrical appliances had failed. This was true of the electric range and oven. At the time of inspection, the homes primary cooking appliance was a
propane camping stove (Figure 11). Stored beneath the open stand on which the stove sat were two chainsaws (Figure 12). These conditions present indoor air quality issues relating to combustion by-products and volatile organic compounds.

**Occupant Issues:** The home had four occupants with no reported health problem that could be related to mold.

**Discussion / Recommendations:** The mobile home was in such poor condition, that replacement, rather than repair, should be investigated before investing more into the house. If repair is began, numerous health and safety issues of critical concern follow:

- Addressing electrical problems, probably requiring new service and rewiring of the residence.
- Addressing the heating system. If the residents resist the installation of a central heating system, than the current wood stove should be upgraded. This would include the installation of a fireproof floor covering, and the installation of a new, double-walled vent system.
- Upgrades to the kitchen appliances.
- Repair and regular maintenance to the roofing system to prevent leaks and subsequent mold problems.
- The installation of a bathroom exhaust fan.
Appendix B, Cherokee Nation Technical Assessment Report

Inspection Number: 1-3
Address: Rt. 1
Model Type: Ranch
Age: 33 Years
Bedrooms: 3
Foundation: Crawl Space
Heat Type: Wood Stove
Construction: Wood frame w/Brick Veneer
Attic: Stick Framed

Mold and Moisture Conditions: The home had extensive and acute mold and moisture problems.

Rainwater Management: There was no gutter system. The gable roof shed water towards both the front and back of the house.

Site Drainage: The rear of the site drained towards the home (Figure 2). Half of the roof also drained to the rear, creating wet foundation conditions.

Foundation Conditions: The view from the crawlspace access hatch on the outside of the home disclosed saturated soil in the crawlspace. With no apparent vapor barrier covering, the joists and subfloor were water saturated and covered with mold. In some areas the subfloor was completely rotted through (Figure 3). The chaotic structural, plumbing, and mold conditions in the crawlspace and also no exterior ventilation from the crawlspace were visible (Figures 4 & 5).

Bathroom: The toilet was very unstable and had a leaking drain gasket, the apparent cause of the advanced rotting of the subfloor (Figure 6). The water heater for the home...
was located in the bathroom on top of a makeshift stand adjacent to the toilet. Residents indicated that this arrangement was to prevent the water heater from falling through the rotting floor of the bathroom (Figure 7).

**Roof and Attic:** From the exterior, numerous roof problems appeared and were confirmed on the interior, as portions of the ceiling were missing in two bedrooms due to leaks and deterioration. It was possible to look up into the attic space from these rooms (Figure 8). Portions of the ceiling had large mold blooms (Figure 9) and others appeared to be in danger of falling into the residence. A good illustration of how severe the roof leakage had been and how bad the structural deterioration was is noted in Figure 10.

**Mechanical Systems:** The primary heating system consisted of a propane heater in the living room (Figure 11). The heater was vented through a masonry chimney. The other rooms did not have any heat source.

**Occupant Issues:** The home had nine occupants, seven children and two adults. Two of the children had diabetes and one had asthma.

**Discussion / Recommendations:** The residence is in very poor condition. The subfloor in several areas within the residence has completely rotted through, leaving the carpet as the primary structural flooring element. Buckets have been strategically placed to capture water coming in through the roof (Figure 12). Water damage has created significant structural rot and deterioration, as well as extensive mold contamination on ceilings and in the floor framing system.

It is very questionable as to whether it would be economically prudent to repair all of the house's problems, or start anew. Properly repairing of this structure would be very expensive, nearly a "gut rehab." Most of the floor and roof structure would need to be removed and replaced. Based on findings throughout the rest of the structure, it is likely that the walls are also in bad condition. If efforts to repair this structure are initiated, their focus should be on the following:
• Rectifying site drainage issues.
• Addressing rainwater runoff from roof surfaces with gutters.
• Sealing the crawlspace floor to keep ground water out of the structure.
• Removing and replacing the floor structure.
• Fixing the roof structure, sheathing, covering and interior ceilings.
• Performing mold remediation on the interior of the structure.

This list is just the start. Subsequent efforts should address:

• Any problems found within the walls.
• Installation of a central heating system.
• Plumbing problems.

A comprehensive cost estimate should be conducted before any repair efforts are undertaken. The analysis would probably show that it would be more cost effective to demolish the existing structure and build new.

With the presence of an asthmatic child, addressing this family’s housing condition should receive high priority.
Inspection Number: 1-4
Address: Rt. 1 Box 270
Model Type: Modular Home
Age: 2 Years
Bedrooms: 2
Foundation: Piers w/Skirting
Heat Type: Electric Forced Air
Construction: Wood frame
Attic: Closed Assembly

Mold and Moisture Conditions: Extensive mold and moisture problems were present in almost every room. The house clearly suffered from a large moisture load as demonstrated by a high indoor relative humidity. The mold and moisture problems were related to condensation at the base of walls. The home had a musty smell upon entering.

Rainwater Management: There was no gutter system. The gable-end roof shed water towards the front and back of the house.

Site Drainage: The site drained towards the front of the home (Figure 1). Half of the roof also drained to the front compounding the rainwater accumulation on this side of the house.

Foundation Conditions: The house sat on piers and had a metal skirting around its base. A section of skirting was removed to allow inspectors to look beneath the unit. The soil beneath the unit was wet due to rainwater drainage occurring through the crawl space. The fiber reinforced polyethylene that held the insulation in place was violated in two locations. The team reached up through the polyethylene to the fiberglass insulation and squeezed water out of the saturated insulation. More than likely, the entire floor system was saturated, greatly contributing to the overall moisture load exhibited in the house.

Bathroom: The bathroom had a working fan and the toilet was seated tightly to the floor. Mold was present in the bathroom.

Bedrooms and Living Spaces: Condensation and mold growth occurred at the base of the walls in the bedrooms and other living spaces. Moisture content measurements of the wooden baseboards indicated full saturation at these locations. The closet of the east bedroom had so much condensation on the exterior wall of the closet that water was standing on the floor of the closet with associated mold on the wall. The west bedroom had mold growth at both the base of the wall (Figure 2) and the wall/ceiling juncture on the west wall (Figure 3). Similar conditions were noted at the base of the exterior dining room wall.
**Kitchen:** A plumbing problem associated with the kitchen sink drain was solved by placement of a plastic tub beneath the drain. The tub was nearly full at the time of the inspection presenting an ideal place for mold growth (Figure 4).

**Attic:** As in most modular homes, the ceiling assembly was a closed and inaccessible. The roof surface itself was very wavy and, according to one of the residents, the conditions were getting worse (Figure 5). It was likely that the waviness was due to swelling and subsequent buckling of the roof sheathing beneath the shingles as a result of the high moisture load in the interior impacting the attic space.

**Mechanical Systems:** The home had a centrally located electric, forced-air heating system. There was no dedicated return air duct system. The living spaces themselves served as a return air plenum. The louvered door to the mechanical closet allowed return air back to the system. The residents mentioned that in the first winter season the east bedroom of the trailer did not receive any heat. The manufacturer was contacted, who in turn did something beneath the unit, which resolved the problem. The supply ducts were not accessible for inspection, and there is the concern that, since water was discovered in the insulation beneath the home where the supply ducts are located, the ducts were being exposed to moisture. This could result in the forced air system contributing to the high humidity in the house, and the possibility of mold growth in the ductwork.

**Occupant Issues:** The home had six occupants, which can be considered a high occupancy rate for this size structure. While there were no diagnosed ailments, residents complained of headaches and sinus problems.

**Discussion / Recommendations:** This was a two-year-old modular home, having recently replaced an older mobile home. The home will deteriorate rapidly given its current moisture problems. Action should take place quickly if this investment is to be protected.

At the time of inspection, the moisture load (relative humidity) on the interior of the home was enormous. While a measurement of the humidity was not taken, eyeglasses fogged up immediately upon entering the home despite the relatively warm outside temperature (52°F). Double-glazed windows exposed to direct solar radiation (windows one would expect to be dry under almost any circumstance) had extensive water
condensation on the interior. Based on these observations, the relative humidity must have been around 80% or greater. At this level, only slightly cool surfaces would result in condensation, as was exhibited throughout the house. The high interior moisture load had resulted in condensation and mold growth on wall/ceiling junctions, baseboards, and lower walls in several places in the house.

The amount of moisture inside the structure and the sources of that moisture were of great concern. One obvious moisture source came from occupants, through cooking, bathing and respiration. With six occupants, the house was overcrowded which multiplies the occupant-produced moisture.

At this point, the water contained in the floor framing and insulation was an evident moisture source. Whether this moisture was the result of condensation from the occupant sources or other sources was unclear and would require destructive investigation from below the house. Regardless, the interior was sitting over a plastic-sealed floor that was soaked with water.

There were two other related areas of concern: ventilation rates and drying potential. The house appeared tight (low air changes/hour - ACH) relative to the outside. Without a mechanical ventilation system, natural infiltration was the only means for diluting the moisture load in the interior air during the winter. A house with a tight exterior envelope, particularly an overcrowded house, would experience high moisture loads when closed up for the winter. A blower door measurement would be necessary to confirm relative tightness of the building envelope. (Weatherization agencies will often have the expertise to make and interpret this measurement).

A building assembly could get wet without much concern if it were also allowed to dry easily. The drying potential of this home was minimal. All of the interior walls were covered with vinyl wallpaper, which virtually eliminates drying of building cavities to the inside. The exterior was painted and well-sealed with caulk. The bottom of the floor assembly was covered with plastic, which minimized drying of the floor system to the outside space below the home. The moisture that was being produced was having a difficult time leaving the residence.

To address the mold and moisture problems in this house, it was essential to dry out the house and identify any additional moisture sources associated with the floor system. The following procedures were recommended:

1. As soon as weather permits, temporarily remove the skirting around the home.

2. A 6 mil (or greater) plastic vapor barrier should be placed on the soil under the home. Ideally, the vapor barrier should be installed so that rainwater following the grade of the hill from the north will flow under the vapor barrier rather than over the vapor barrier. Perhaps tacking the vapor barrier up on the floor framing on the uphill side will accomplish this.
3. The plastic covering the floor framing should be removed, along with all of the insulation in the floor. This will allow the floor system (framing, sheathing, and insulation) to dry out over a period of time. Once the insulation is dry, it can be reused.

4. The floor system should be examined for potential moisture sources. Particularly:
   a. Are there plumbing leaks?
   b. Is the dryer, exhaust fan, or condensate line spilling into the floor system?
   c. Are there signs of other spills?

   The supply ductwork should also be examined at this time. Is it well-sealed? Is there evidence of moisture entering the ductwork and contributing to the interior moisture load? What was the nature of the previous repair? It may require some dismantling of the ductwork to answer these questions.

5. All sources of moisture in the floor system should be repaired.

6. Once the floor system has dried out, the insulation can be re-installed in the floor. Rather than a solid polyethylene cover, which minimizes drying potential, a covering that allows for drying is recommended. A possibility would be the plastic temporary fencing material (perforated, orange, plastic stuff). This would do an adequate job of supporting the insulation, while allowing the floor system to dry to the exterior when required.

7. With the removal of the solid plastic undercover, the vapor barrier covering the soil should remain to prevent evaporation of soil moisture below the house. Efforts should be made to reduce the rainwater that flows under the home. Having the site drain towards the structure is undesirable. A swale could be cut into the hillside on the uphill side of the home to divert water away from the structure. A gutter on the front side of the home could be installed to divert the rainwater water coming off of the roof. If these solutions are not practical, then providing channels for rainwater to flow under the house, and ensuring that flowing rainwater travels below the plastic groundcover, will be essential.

8. The skirting can be re-installed. It is recommended that an intentional hatch be provided to allow for periodic inspection. Currently, access is available only by unscrewing the skirt panels.

Following these repairs, the house should be closely monitored next winter. This will take a combined effort by the resident and housing authority. Interior relative humidity should be monitored over the course of the winter. In Oklahoma’s climate, a wintertime interior relative humidity of 50% and below will prevent condensation and mold growth. Ventilation and/or dehumidification may be necessary to prevent recurring problems.
One inexpensive ventilation strategy would be to install a humidistat control on the bathroom fan to be used during the winter months, allowing it to run as often as needed. If this is not sufficient, an engineered ventilation system should be considered. Different systems are available including supply only, exhaust only, and balanced (equal supply and exhaust) systems. Given Oklahoma's mild winter climate, the expense of a heat recovery ventilation system (HRV) would not be warranted. A mechanical engineer familiar with residential ventilation systems would be helpful in preparing a design. Providing dehumidification would be another option, particularly if the dehumidifier was set up so that residents did not have to constantly empty reservoirs. They should drain directly to the exterior and away from the structure.

Reducing the moisture load in the house will halt the buckling of the roof sheathing. It will not, however, reverse that condition and return the roof sheathing to its original flat configuration. At this point, that is a cosmetic consideration. While it may not look ideal, the roof should provide decent service.

The current mold contamination should be cleaned up with soap and water.

At this point, it is not likely that the moisture problems have caused significant deterioration to the structure. However, if left unchecked, this residence could deteriorate rapidly. Roof, wall and floor sheathing will swell, delaminate, and decompose fairly quickly. This new modular home represents a valuable investment, and should have a long service life.
Figure 1 – Address not available

Inspection Number: 1-5
Address: Unknown
Model Type: Former Senior Center
Age: Unknown
Bedrooms: Many
Foundation: Slab on Grade
Heat Type: Forced Air
Construction: Block Walls
Attic: Wood Framing

Mold and Moisture Conditions: Mold was present on particleboard shelving that was sitting on the floor adjacent to an exterior wall (Figure 2). Due to low-light conditions, because the power to the facility had been disconnected and the windows had been boarded-up, it was difficult to assess mold and moisture problems.

Rainwater Management: The building did not have any gutters, however, the building did have generous, yet deteriorating overhangs (approximately two feet), which at least shed water a slight distance away from the structure (Figure 3).

Site Drainage: The site was relatively flat except at the rear of the structure where it sloped gently away from the building.

Foundation Conditions: The foundation for this building was a slab-on-grade.

Attic: Was not inspected.

Mechanical Systems: Rooftop mechanical units (Figure 4). Power to the building had been disconnected so it was not possible to determine whether the units functioned. Distribution and return-air ducts were located in the attic space.

Occupant Issues: Building was vacant.

Discussion / Recommendations: This building was formerly a senior housing center, but currently was vacant and boarded up. Although the roof was in need of new shingles and some repair due to leakage, there were no sags and all roof surfaces appeared to be very planar indicating a sound structure. The exterior block walls appeared to be in good condition.
The floor plane of the interior was just slightly above grade making the entry to the building very accommodating for handicapped and elderly. The double-loaded corridors were wide. The interior was subdivided into sleeping rooms with centrally located kitchen, dining, and assembly areas.

From a structural standpoint the building envelope appeared to be in good condition with only slight deterioration in the building eaves. However, if the plumbing supply lines, traps, and the sprinkler system were not drained before the building was vacated, they were probably compromised at the time of inspection due to freezing water.

Depending on how the building might be reused, it had great potential. The building appeared structurally sound in all respects. Mechanical systems would need to be refurbished, as would the sprinkler system. All windows would need to be assessed for condition and possible replacement.

The mold that was found in this facility was minor and due to particleboard being in direct contact with a floor surface along an exterior wall (Figure 4). Although it was very difficult to see inside the rest of the facility, mold remediation was probably the least of this facility’s needs.
Inspection Number: 2-1
Address: Rt. 3, Box 172-2, Muldrow, OK
Model Type: Ranch
Age: 21 years
Bedrooms: 4
Foundation: Crawl Space
Heat Type: Electric oven
Construction: Wood frame
Attic: Wood Truss with fiberglass batt insulation. Two small gable vents

Mold and Moisture Conditions: There was a significant moisture load in the house, as condensation was visible on the inside of double paned windows. Moisture generation was from the crawlspace and the bathroom, resulting in mold and moisture damage in the bathroom, exterior closets, ceilings of the bedrooms, and within the attic space above the bathroom. It was probable that there was moisture damage within the exterior wall adjacent to the bathroom. Lack of central heating contributed to these moisture conditions.

Rainwater Management: The site sloped gently front to back. There was a modest slope away from the foundation on the two side and rear elevations.

There was no roof drainage system (gutters, downspouts, leaders, etc.). This lack of rainwater management contributed to a damp crawlspace.

Foundation Conditions: The house was built on a vented crawl space. The site was not excavated well, and there was minimal access (little headroom) in the crawlspace. There was no vapor barrier over the dirt in the crawlspace. The crawlspace appeared damp, with the lack of roof drainage as a major contributing factor. There were locations in the house that indicated rotting flooring. For example, the wood stove had not been installed this current winter for fear that the floor could not support its weight.

Bathroom: The exterior inspection revealed a section of siding with peculiar water staining (Figure 2). A closer examination indicated that water was not a result of roof leakage or rainwater, but was migrating from the interior to the exterior. The condition was active, as drips of liquid water could be seen on the bottom edge of the clapboard.
Clearly, the building cavities on this portion of the wall were saturated with moisture. An examination of the interior floor plan indicated that this specific section of outside wall was the precise location of the bathroom.

The bathroom was small, with the shower placed on the exterior wall (Figure 3). There was no window. While the heater and light of the bathroom exhaust fan unit were operating, the exhaust fan itself was inoperable. In this case, the bathroom was a high moisture load source, with moisture migrating by both diffusion and convection, and perhaps direct leakage, into the wall cavity. The moisture source in the bathroom was also contributing to the overall moisture load of the house, leading to condensation problems and mold in other locations (Figure 4).

There was a general lack of maintenance and cleaning in the bathroom. The shower was grimy, and there was moisture damage and mold growth behind the toilet.

**Attic:** There was significant mold growth on the roof sheathing above the bathroom (Figure 5). There was no vent on the bathroom exhaust fan, which implies that when the fan was operating, the moist air was venting directly into the attic. This resulted in condensation on the cold roof sheathing in the winter months. The mold growth is certainly related to this improper installation. Given the high moisture load in the bathroom, continuing mold growth may still be occurring as a result of moisture migration by convective air currents around the fan housing.

There was approximately 6” of fiberglass batt insulation, though some of the coverage was poor. There was minimal attic ventilation, with just two small gable attic vents.
Bedrooms: There was evidence of mold contamination related to winter condensation problems in both bedrooms adjoining the bathroom. There was some mold growth at the wall/ceiling juncture on exterior wall of one bedroom (Figure 6), and far worse mold growth on the exterior walls of the bedroom closets (Figure 7). This was the result of a high moisture load in the house, lack of heat to the bedrooms, and considerable clutter in the closets that prevented air circulation and heat to reach the outside walls of the closets (Figure 8). Proximity to the bathroom (adding additional moisture by diffusion and convection through the shared walls) and poor insulation in the exterior walls may have contributed to this problem.

Kitchen: There was no evidence of moisture and mold problems in the kitchen.

Mechanical Systems: The house featured no central heating system. According to the residents, heating typically was provided through the use of a wood stove. At the time of inspection, the wood stove had not been installed, and the sole source of heat was from the electric oven in the kitchen. This resulted in relatively cold conditions in portions of the house. The bedrooms with the mold conditions, in particular, were noticeably cold. This arrangement contributed significantly to the mold contamination by providing chilled surfaces for condensation and mold growth to occur.

Occupant and Health Issues: There were no specific health problems reported by the residents. The occupants could play a critical role in preventing further mold contamination by:

- Using the bathroom exhaust fan.
- Maintaining the bathroom in a clean fashion.
- Clearing the closets of clutter to allow for heat and airflow to reach exterior walls.
Discussion / Recommendations:

1. A continuous vapor barrier should be placed over the floor of the crawl space.

2. A roof drainage system (gutters, downspouts, leaders, etc.) should be installed. Rainwater should be diverted to the slope in the back of the house.

3. The exterior wall of the bathroom and adjacent bedroom closets should be dried and repaired. The best approach would be to remove the shower unit, exposing the wall, and remove all of the interior drywall to expose the cavities. If there is any insulation in the wall, it should be removed and discarded, and the wall allowed to thoroughly dry from its current saturated condition. The condition of the framing and exterior sheathing should be assessed at this time and repairs made. Any mold should be cleaned up in this area. Once dry, this area can be rebuilt and a new shower enclosure installed. A vapor barrier should be placed on the interior of the wall and the wall sealed to ensure an airtight wall assembly, thus minimizing the potential for moisture migration through the wall cavity.

4. A new bathroom fan should be installed. The exhaust fan should be vented to the outdoors through the roof or the soffit overhang. A through-the-wall fan could also be installed above the shower to the exterior. Controls for the exhaust fan should be wired to the lights and feature a time-delay mechanism for the fan.

5. Insulation in the attic should be continuous. Bypasses through the ceiling plane (plumbing vents, electrical wires, exhaust fan, around chimneys, etc.) should be sealed with expanding foam sealant to minimize moisture migration from the interior into the attic. Additional attic ventilation would be helpful in addressing sheathing mold contamination, but it is secondary to ensuring an airtight ceiling plane. If any residents are diagnosed with asthma or a sensitivity to mold, the attic sheathing should be cleaned of mold contamination.

6. The bedrooms should be heated in the winter. Personal possessions and clothes should be kept free from the exterior walls in the closets to allow for airflow. The exterior cavities should be checked for the presence of insulation (perhaps at the time of the bathroom renovation). The existing mold contamination should be cleaned up.

7. The house would benefit from the installation of central, forced air heating. Distribution could be run through either the attic or crawl space (though both spaces are tight to work in). Because these areas are outside the conditioned space, ductwork should be insulated and all joints should be sealed with duct mastic.

8. Occupants should be encouraged to maintain the bathroom in a clean, dry condition.
Inspection Number: 2-2
Address: Rt. 5 Box 6520 Stillwell
Model Type: Ranch
Age: Unknown
Bedrooms: 8
Foundation: Crawl Space
Heat Type: Wood stove
Construction: Wood frame
Attic: Wood frame with 2"-3" cellulose insulation. Ventilation in addition only.

Mold and Moisture Conditions: There were minor mold conditions in the bathroom. There was significant mold contamination on exterior walls in the bedroom addition and on the lower exterior wall in the dining room.

Rainwater Management: The site was generally flat with little to no pitch away from the house. In localized areas, the ground pitched toward the foundation. There was no roof drainage system (gutters, downspouts, etc.).

Foundation Conditions: The house was built on a damp crawl space with no vapor barrier over the soil. There was no insulation in the floor system or along the foundation walls, thus the crawl space was a major moisture source for the house.

Bathroom: There was minor mold growth around the tub and tile surround in the bathroom (Figure 2), which could be solved with regular cleaning and maintenance. There were indications of plumbing leaks around the base of the toilet. There was no bathroom exhaust fan, but a window was present.

Bedrooms: The bedroom in the addition (left side of Figure 1) showed mold growth at the wall/ceiling juncture on the exterior wall (Figure 3). In this and other bedrooms, mold was also found at the...
bottom of exterior walls behind the beds and in the closets (Figures 4 and 5). A similar area of mold contamination was noted on the exterior wall of the dining room. These areas of mold contamination were the result of condensation during the winter months. See the Discussion/Recommendation section.

**Kitchen:** There were no mold or moisture conditions noted in the kitchen. The residents reported that there was significant mold growth on the exterior wall prior to a recent renovation. This contamination has not returned.

**Attic:** While there was no access to the attic over the bedroom addition, the attic of the main structure could be examined. The attic was wood framed, and contained minimal cellulose insulation, about two to three inches. The insulation was not well distributed, with low density particularly near the soffit (Figure 6). There was no evidence of mold on roof sheathing. There were no soffit or ridge vents in the main structure, but vents had been installed in the fascia on the bedroom addition (Figure 7). These vents are contributing to the mold growth at the wall/ceiling juncture in the bedroom by creating a wind washing effect through the insulation and chilling this location further.

**Heating Systems:** There was no central heating system in the house. The sole heat source was a wood stove in front living room (Figure 8).
was an unvented propane heater in the same room that had been disconnected, and was no longer in use. The absence of heat supply to the addition was a contributing factor in the mold contamination.

**Occupant Issues:** The house could be described as overcrowded, with eight occupants (and a ninth on the way) residing in a relatively small house. This condition placed an additional moisture load on the house. One of the children, a 13 year old, suffered from asthma. Additionally, there were concerns over the youngest baby’s respiratory health, for which the child was receiving treatment. The residents were adding humidification to the house by placing a large pot of water on wood stove (Figure 8). A house with existing mold conditions is unlikely to be overly dry; people suffer from overly dry conditions only when the relative humidity falls below 25%. This practice of humidification should be discouraged.

**Discussion / Recommendations:** Several factors were contributing to the mold contamination in the addition bedroom:

1. Minimal insulation in the ceiling allowing for cold temperatures at the wall/ceiling interface.

2. Attic ventilation in the fascia of this addition, which allowed for wind washing through the insulation, which further chilled the exterior corners.

3. This bedroom was the farthest room from the lone heat source in the house, and was naturally cooler for this reason. Cooler surfaces are more prone to condensation and resulting mold growth.

4. The house was subject to a high moisture load in the winter. The primary moisture sources were:
   
   a. Overcrowding (eight residents in a small house).
   b. Wet crawl space.
   c. Lack of bathroom ventilation.
   d. Humidification being created at the wood stove.

Insufficient insulation in the wall cavities and at the band joist may also be contributing to the condensation problems at the bottom of the exterior walls in the bedrooms and bedroom closets.

Efforts to address these mold problems should focus on both reducing the moisture load in the house and warming the affected surfaces. Specifically:
1. A continuous vapor barrier should be placed over the floor of the crawl space.

2. A roof drainage system (gutters, downspouts, leaders, etc.) should be installed. Rainwater should be diverted away from the house in all locations.

3. A new bathroom exhaust fan should be installed. The exhaust fan should be vented to the outdoors through the roof or the soffit overhang. Controls for the exhaust fan should be wired to the lights and feature a time-delay mechanism for the fan.

4. Insulation in the attic should be continuous, and upgraded to a minimum of six inches of cellulose insulation. Care should be taken to ensure that the insulation covers the top plate over the exterior walls. If attic ventilation is retained in the addition bedroom, it should be channeled from the vent through a styrofoam baffle, and not allowed to wash through the insulation.

5. The bedrooms should be heated in the winter. Ideally, the house would benefit from the installation of central, forced air heating. Distribution could be run through either the attic or crawl space (though both spaces are tight to work in). Because these areas are outside the conditioned space, ductwork should be insulated and all joints should be sealed with duct mastic.

6. The exterior cavities should be checked for the presence of insulation.

7. Occupants should be encouraged to maintain the bathroom in a clean, dry condition. They should be discouraged from adding humidification in the winter.
Inspection Number: 2-3
Address: Unknown
Model Type: Ranch
Age: Around 20 years old
Bedrooms: 3
Foundation: Slab-on-grade
Heat Type: Unvented propane space heater
Construction: Wood frame with brick veneer
Attic: Wood or truss frame, with soffit and gable vents

This house was undergoing rehabilitation. Residents had been temporarily relocated during the work, and were not available at the time of the inspection.

Mold and Moisture Conditions:
There were numerous indications of past roof leaks, but these leaks appeared inactive at the time. There was one area of severe mold contamination that was the result of a plumbing leak in an interior partition wall.

Rainwater Management: There was no roof drainage system (gutters, downspouts, etc.), allowing rainwater to spill next to the foundation. The site had generally good drainage, with a strong slope away from the house on the front elevation (Figure 2). There were built in foundation gardens constructed of flagstones at both ends of this elevation. These constructions, in the absence of a roof drainage system, could serve to trap the rainwater that would otherwise spill off of the roof and flow away from the house. This could raise the potential of moisture migration through the slab.

Foundation Conditions: Despite the condition just mentioned, there was no indication that the slab foundation was contributing to the moisture load in the house. The bedroom floors were covered with vinyl tile, and there were no identified areas where foundation moisture was causing these tiles to lose adhesion and delaminate from the substrate. The living room was carpeted, but there was no sign of moisture migration through the slab foundation affecting the carpet.
Roof and Attic Conditions: It was clear that there have been several past leaks through the roof. Numerous locations of water staining on the ceilings were evident throughout the house (Figure 3). The house had recently received a new shingle roof, and there was no indication that any of the roof leaks were active. The attic was insulated with an adequate depth of fiberglass. There was no indication of mold on the roof sheathing or active leaking through the roof.

![Figure 3: Evidence of past roof leaks throughout house](image)

Bathroom: There was no mold or moisture problem identified in the bathroom. There had been a prior link in the plumbing or drain line associated with the sink, which had caused some mold growth in the base of the sink cabinet (Figure 4). Plumbing repairs had been performed, and the problem was no longer active.

![Figure 4: Mold growth from prior plumbing leak](image)

Bedrooms: There was a serious mold problem in the closet of the front bedroom. The floor and base of the closet was wet, with considerable mold on the floor and gypsum board of an interior partition wall (Figure 5). The water source was a leaking plumbing supply line going to an exterior hose bibb. No other problems were identified in the bedrooms.

![Figure 5: Plumbing leak within interior partition wall (left). Resulting damage and mold contamination on opposite side of wall (right).](image)
Kitchen: There were no mold or moisture conditions noted in the kitchen.

Heating Systems: There was a gas-fired, forced-air, central heating system installed in the house, located in a closet off of the front living room. This system, however, was no longer functioning. Instead, the sole heat source was an unvented propane space heater installed nearby, with a copper gas line running over the carpet (Figure 6). Unvented combustion appliances present health hazards from carbon monoxide and other by-products of combustion. As water vapor is a principal combustion byproduct, the appliances are also a significant moisture source. The exposed copper gas line also presented a health hazard.

Occupant Issues: The residents of the home were temporarily relocated, and not available to interview. An unidentified piece of medical equipment was located next to the bed in the back bedroom (Figure 7). It would appear that one of the residents had issues with respiratory health.

Discussion / Recommendations:

1. A roof drainage system (gutters, downspouts, leaders, etc.) should be installed. Rainwater should be diverted away from the house in all locations.

2. The plumbing leak in the partition wall should be repaired. Damaged drywall should be removed and discarded, and any mold in the wall cavity cleaned up. The area should be allowed to thoroughly dry prior to installing new drywall.

3. Prior to re-occupation, the mold in the base of the bathroom cabinet should be cleaned.

4. If not part of the current rehabilitation work order, the central heating system should be repaired and re-activated. Use of the unvented propane space heater should be avoided in all but emergency situations.