FORT BELKNAP INDIAN COMMUNITY HOUSING
DEPARTMENT TRIP REPORT
Assessment of Mold and Moisture Conditions

Final Report

Date:
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Office of Native American Programs

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FORT BELKNAP INDIAN COMMUNITY HOUSING DEPARTMENT TRIP REPORT

INTRODUCTION

Robert Nemeth and Paul Knight from Magna Systems conducted a site visit at Fort Belknap Indian Community on March 4-7, 2003. The purpose of the site visit was to provide technical assistance to the Fort Belknap Indian Community Housing Department (FBICHD) 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 on the findings and recommendations is found in PART II: Technical Housing Assessment Report: Examining Mold and Moisture Conditions of Homes on the Fort Belknap Reservation.

BACKGROUND INFORMATION

The FBICHD is located in Blaine and Phillips Counties in the State of Montana. The Fort Belknap Indian Community is located between the Milk River and Little Rocky Mountains. The combined reservation and trust lands encompass 705,067 acres of rolling plains and grasslands of north-central Montana. The reservation is situated close to the Canadian border. The average annual precipitation is 11.95 inches and snowfall is 27.6 inches. The average monthly temperature range is 15.3° F in January to 69.6° F in July. Approximately 2,869 Native Americans reside on the Reservation and trust lands. The housing authority maintains 249 Low Rent homes and 311 Mutual Help homes.

The assessment team investigated eleven homes located on the reservation. All the homes were ranch style with two or three bedrooms, built over crawl spaces. Most used natural gas furnaces as the primary heating source. The homes ranged in age from two years to thirty-four plus years.

Day 1: Wednesday, March 4, 2003

This was a travel day to the Indian community.

Day 2: Thursday, March 5, 2003

On Thursday morning, the assessment team met with Mr. Ed Longknife, Executive Director of the FBICHD. During the meeting, the team discussed the on-site assessments process. The housing authority’s staff selected eleven properties for inspection. Six homes were inspected that day.

Day 3: Friday, March 6, 2003

On Friday, the assessment team inspected five homes. Digital photographs were taken at each site to record conditions. The inspection process involved visual assessments of both
interior and exterior conditions, the measurements of relative humidity, airflow, and moisture content reading and discussion with residents when available. PART II: Technical Housing Assessment Report: Examining Mold and Moisture Conditions of Homes of the Fort Belknap Indian Community provides a detailed analysis of findings and recommendations for the homes investigated at the Fort Belknap Indian Community.

Day 4: Saturday, March 7, 2003

This was a travel day.

FINDINGS

The site assessment team inspected eleven homes of Fort Belknap Indian Community 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 six of the eleven residences. Many of the sites were flat with no slope away from the foundation. In two cases, a hillside drained toward the building. Ten 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 several instances there were no vapor barriers covering the soil in the crawl spaces. In some cases, the wet conditions promoted mold growth.

3. Seven 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.

4. Poor to nonexistent bathroom exhaust ventilation systems were significant issues in the inspections of Fort Belknap housing. Operable exhaust fans were missing in five of the eleven homes.

5. Three inspected houses were subject to overcrowded conditions. Overcrowding increases the moisture level produced from human sources, contributing to elevated interior moisture loads, and ultimately lead (if other conditions are in place) to mold contamination from condensation problems. Condensation and related mold contamination occurred in two inspected houses with overcrowded conditions.

6. Ten homes had central heating systems and one had baseboard electric heat.

7. Several maintenance issues contributed to mold and moisture conditions. Plumbing leaks were evident in seven of the eleven houses. Two others had plumbing problems.
An overview of findings and recommendations for the houses that were inspected are included in the PART II: Technical Housing Assessment Report, Section 3 – Findings, and a more detailed discussion and analysis of the findings of each house can be found in Appendix B: Housing Assessment Results.

PROGRAMMATIC RECOMMENDATIONS

A particular challenge to all housing authorities is the development of a service-delivery system that effectively and promptly addressed mold and moisture conditions. This requires a partnership between the housing authority and residents. A system could include training for the maintenance staff on how to implement the technical recommendations as well as training for residents on their roles and responsibilities as renters and homeowners. In many cases, moisture problems develop, but go unreported and unrepaird, which results in significant mold contamination that could have been avoided. Some strategies follow:

1. Require attendance at annual homeowner/renter clinics as part of the annual recertification process. These clinics could provide instruction on home maintenance issues such as identifying and repairing leaks, proper use of fans, causes of mold, cleanup of mold, gutter maintenance, and other issues that contribute to the wellbeing of building occupants.

2. Ask occupants to complete a survey based on Housing Quality Standards (HQS) with additional questions on mold and moisture conditions in their homes during the annual recertification process. Having the residents complete the survey further engages them in their own home maintenance. Furthermore, the survey responses would provide additional information to the housing authority on any unreported problems, especially leaks and inoperable fans that might contribute to an unsafe, unhealthy home environment.
PART II

FORT BELKNAP INDIAN COMMUNITY HOUSING DEPARTMENT

TECHNICAL HOUSING ASSESSMENT REPORT

EXAMINING MOLD AND MOISTURE CONDITIONS IN HOMES OF THE FORT BELKNAP INDIAN COMMUNITY HOUSING DEPARTMENT

Executive Summary

Introduction

Section 1: Methodology

Section 2: Fort Belknap Indian Community Housing Types

Section 3: Findings

Section 4: Technical Discussion and Recommendations

Appendix A: Housing Survey Summary Site Visit Report

Appendix B: Housing Assessment Results
EXECUTIVE SUMMARY

The site assessment team inspected eleven homes of Fort Belknap Indian Community 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 six of the eleven residences. Many of the sites were flat with no slope away from the foundation. In two cases, a hillside drained toward the building. Ten 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 several instances there were no vapor barriers covering the soil in the crawl spaces. In some cases, the wet conditions promoted mold growth.

3. Seven 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.

4. Poor to nonexistent bathroom exhaust ventilation systems were significant issues in the inspections of Fort Belknap Indian Community housing. Operable exhaust fans were missing in five of the eleven homes.

5. Three inspected houses were subject to overcrowded conditions. Overcrowding increases the moisture level produced from human sources, contributing to elevated interior moisture loads, and ultimately (if other conditions are in place) led to mold contamination from condensation problems. Condensation and related mold contamination occurred in two inspected houses with overcrowded conditions.

6. Ten central heating systems and one electric baseboard heating system existed in the inspected homes.

7. Several maintenance issues contributed to mold and moisture conditions. Plumbing leaks were evident on seven of the eleven 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

Robert Nemeth and Paul Knight from Magna Systems conducted a site visit at Fort Belknap Indian Community on March 4-7, 2003. The purpose of the site visit was to provide technical assistance to the Fort Belknap Indian Community Housing Department (FBICHD) in assessing mold and moisture condition in housing units. This report summarizes activities and issues addressed while on site. A detailed analysis on the findings and recommendations is found in PART II: Technical Housing Assessment Report: Examining Mold and Moisture Conditions of Homes on the Fort Belknap Indian Community.

The FBICHD is located in Blaine and Phillips Counties in the State of Montana. The Fort Belknap Indian Community is located between the Milk River and Little Rocky Mountains. The combined reservation and trust lands encompass 705,067 acres of rolling plains and grasslands of north-central Montana, close to the Canadian border. The average annual precipitation is 11.95 inches and snowfall is 27.6 inches. The average monthly temperature range is 15.3° F in January to 69.6° F in July. Approximately 2,869 Native Americans reside in the Indian Community and trust lands. The housing department maintains 249 Low Rent homes and 311 Mutual Help homes.

The assessment team investigated eleven homes located in the Indian Community. All the homes were ranch style with two or three bedrooms. All the homes were built over crawl spaces and all but one used a natural gas furnace as the primary heating source. The age of the homes ranged from two years to over 34 years.

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. Additionally, the assessment team inspected the plumbing, localized ventilation, water entry and other moisture source issues in kitchens, bathrooms, basements, crawl spaces, utility rooms and attics.

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

Floor framing Moisture Content (MC) readings were taken at several residences. 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 the Table of Appendix A in this report. The findings from individual house inspections are presented in Appendix B.

SECTION 2 – FORT BELKNAP INDIAN COMMUNITY HOUSING TYPES

The FBICHD is responsible for 560 housing units in various programs. The assessment team examined eleven housing units for mold and moisture. These units do not represent a typical cross-section of the units under their management, since they were not based on a random sample. Three units were manufactured homes; the other eight units were site-built homes.

All of the site-built homes were older wood-framed ranch houses on crawl spaces. There were twenty-two new manufactured homes that were two years old and set on a site-cast concrete stem-wall crawl space foundation.

SECTION 3 – FINDINGS

The assessment team found visible mold growth in all eleven inspected houses. In some cases, mold contamination was slight and generally limited to bathrooms. In other cases, mold contamination was extensive and acute throughout the house. Mold contamination is always associated with moisture problems. Seven general findings based on the inspection follow:

3.1 Exterior Site Drainage and Rainwater Management

Site drainage and rainwater management is essential to maintaining dry foundations, and ultimately dry houses. Site drainage was rated poor or worse at four of the eleven 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. Additionally, ten houses had no roof drainage systems (gutters, downspouts, leaders, etc.), a condition that can place a tremendous moisture load on the foundation and the house. All inspected crawl spaces were wet for these reasons. Section 4.1 discusses site drainage and rainwater management in more detail.
3.2 Crawl Spaces

The crawl spaces were damp primarily due to site drainage and rainwater management problems. Plumbing leaks and HVAC condensate draining into the crawl space also contributed to wet crawl spaces. Although several of the homes had well installed vapor barriers covering the dirt floors, however, some of the crawl spaces had no vapor barriers. In some cases, the wet conditions were promoting mold growth. Plumbing leaks contributed to damaged subfloor. The damage did not appear to have compromised the structural integrity of the plywood, however, left unchecked, the leaks would eventually result in safety problems. Wet crawl spaces are a leading source of excess moisture load in houses. See Section 4.2 for a discussion of crawl space design and construction.

3.3 Winter Moisture Condensation

Seven houses suffered from mold growth due to 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. 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 also related to the condensation problem.

3.4 Bathrooms and Bathroom Exhaust Ventilation

Lack of functioning or poorly operating bathroom fans were significant issues in the inspections of Fort Belknap Indian Community housing. Bathrooms, by the nature of their function, commonly develop localized mold problems. Plumbing problems, both past and present, were identified in all of the houses. Lack of cleaning and maintenance caused mold problems in bathrooms of seven houses.

Bathroom ventilation can play an important role in reducing interior moisture load. Operable exhaust fans were missing or nonfunctioning in four homes. Bathrooms and localized exhaust ventilation is discussed in Section 4.4.

3.5 Overcrowded Conditions

Three of the inspected houses were subject to overcrowded conditions. Overcrowding increases the moisture level from human sources, contributing 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 the inspected houses with overcrowded conditions. Discussion of human moisture sources can be found in Section 4.5.

3.6 Heating Method and Heat Distribution

Of the eleven inspected residential properties, all but one was heated by a central heating system, and the other had electric baseboard heat. Heating method and heat distribution play a vital role in preventing wintertime mold and moisture problems. Heating systems are discussed in Section 4.6.

3.7 Maintenance Issues

Several maintenance issues contributed to mold and moisture conditions.

- Plumbing and/or bathroom fixture leaks were identified in seven of the eleven houses. Three homes had tub surrounds that either had holes in them, which allowed water into the wall, or had compromised caulk joints where the surround meets the tub. Two other homes featured leaks in drain lines. Maintaining plumbing in proper working order is a high priority maintenance item. Plumbing leaks that persist for months or even years can lead to severe structural damage and mold problems.

- Two of the eleven houses had bath fans that did not work, three had fans that barely worked and the rest had no fan in the bathroom. Bathing produces an excess amount of moisture that must be removed from the home. Frequently, bathrooms are the first rooms to exhibit any sign of mold growth because of the recurring high moisture load in these spaces. Maintenance of bathroom fans and replacement of broken fans should be high on the maintenance priority list.

- 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 could keep mold conditions under control. The presence of clutter in closets and on exterior walls could 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 Fort Belknap Reservation.
4.1 Site Drainage and Rainwater Management

Site Drainage

The roof of a building site should be designed and built so that the rain landing on the roof moves out to the edge of the roof. As rain falls on a soil surface, some 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. Houses that allow water to accumulate in the soil in contact with the foundation will have problems. The best way to prevent mold and moisture problems in houses is to ensure that rainwater moves off the roof, across the site and off the property. 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 next to the foundation is dry.

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. Water management design making use of funnels (such as valleys, gutters or swales) requires maintenance to ensure the funnels 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 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 and 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.

• Direct the water at the base of the downspout away from the foundation of the building (Figure 1). 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 allowed to dump close to the foundation and into the backfill, the water will concentrate next to the foundation—precisely the wrong place for water to be. The traditional way to discharge water away from the house involves the use of downspout extenders (sections of straight downspout) or splash blocks. However, both of these are often disturbed when lawns are mowed. A better alternative is to 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 gutters 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 2). 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 3).

4.2 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 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. Poor 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 Fort Belknap housing violated several of these points. Several crawl spaces had no vapor barriers covering the base of the crawl space, and were marginally insulated. The crawl spaces were wet from poor rainwater management and ground moisture. 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 (Figure 4), 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 crawl space, all joints and seams should 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.
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 5 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 level and run into 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.
4.3 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.

Two approaches could address this 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.

Several of these moisture sources were identified in the Fort Belknap houses that had experienced 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 each respective section.

Especially in 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. However, the problem can occur at a reasonable interior humidity if there is a specific construction flaw that allows a surface to get chilled in the winter.
A common condition leading to winter condensation and mold problems occurs in closets on an exterior wall. 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 closet, which would distribute heat to the closet exterior surface
- Closet clutter that prevents airflow and heat reaching the closet exterior wall
- Clothes hanging against the wall which act as insulation and lower the temperature of the wall

Furthermore, a relatively cold room also contributes to this problem. Ensuring that the exterior wall of the closet does not get chilled will prevent this mold condition. 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 comfortable temperature. Exterior walls should be insulated. Again, the moisture load in the house should be kept at a minimum.

The wall/ceiling juncture on exterior walls also commonly experiences chilling and subsequent condensation and mold contamination. This is a very common problem in northern climates in older ranch-style homes with low-pitched roofs. This problem was identified in Fort Belknap housing, as well.

These are three reasons why the exterior wall/ceiling juncture gets cold (Figure 6):

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.

Figure 6: 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.
3. The geometry of the corner may prevent slow-moving currents of warm air from reaching into the corners.

Dark spots occur where the interior surfaces are the coldest because these are the hardest places 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. 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 push the insulation out to the edge. With 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 7. 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 major drawback. 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 help prevent wintertime mold and moisture problems.

4.4 Bathroom Mold Problems

Many mold and moisture problems in homes occur in bathrooms. This is normal, because they are the wettest 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 hard to detect leak such as a leak at the toilet flange or a leak at a shower drain require careful inspection.

Bathroom users should be careful. Shower curtains should be used so 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. Spills should be cleaned up promptly. Dirty and discolored spots should be cleaned. 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 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 and kitchen exhaust fans as well as 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.

Bathroom exhaust fans should exhaust between 50 and 70 cubic feet per minute (CFM). The effectiveness of exhaust fans depends 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 than ribbed ductwork. Round, smooth sheet metal ductwork is recommended for all types of exhaust ventilation. 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. 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.

However, human moisture sources alone will not produce enough moisture to cause winter condensation and mold problems in the winter. Two circumstances under which human moisture sources may result in problems include:

1. Overcrowding. When the number of residents living in a house clearly exceeds the expected capacity of the house, the moisture burden increases. Each person participates in the moisture-producing activities (breathing, cooking, washing, etc.) to increase the moisture load. 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 a house is both overcrowded and has 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 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 experience in residential ventilation systems would be valuable when addressing a problem of this kind.

4.6 Heating Systems and Moisture Control

In winter heating systems provide comfort for the occupants. Heating systems can also impact winter moisture problems in several ways. Two critical ways follow:

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 significant 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 the major living spaces of the house. A properly designed and functioning heating plant and distribution system keeps all the rooms warm. This minimizes the potential for chilled surfaces, which are potential condensation and mold contamination sites.
Economic reasons sometimes cause residents to limit the heating of spaces such as bedrooms. Although this is understandable, it can also contribute to chilled exterior surfaces and result in condensation and mold growth.

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 with the greatest potential for condensation problems are 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.

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 condensation on pipes
- Use of sump pumps
- Humidifiers
**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>
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<th>Site Drainage Problems</th>
<th>Gutter System Problems</th>
<th>Leaks From Exterior</th>
<th>Wet Basement or Crawl Space</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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Appendix B, Fort Belknap Indian Community Housing Department
Technical Housing Assessment Report

Inspection Number: 1-1
Address: Mt 10-5 E8
Model Type: Frame Ranch
Age: About 30 years old
Bedrooms: 3
Foundation: Concrete block crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Cellulose Insulation

Mold and Moisture Conditions: This home had slight mold and moisture problems.

Rainwater Management: The site was relatively flat. There was no roof drainage system (gutters, downspouts, etc.).

Crawl Space Conditions: The house was built on a concrete block crawl space very low to the ground. There was insufficient foundation height for installing crawl space vents in the concrete block wall; therefore they were installed in the band joist. The crawl space was wet. The block was insulated with eight-inch wide by 3/4 inch thick fiberglass strips that were glued to the block (Figure 2). Some strips were loose and separated from the block exposing a wet surface on the face of the block. Although not evident, conditions existed for mold to flourish. The crawl space floor did not have a vapor barrier, which could have contributed to the condensation on the block walls.

Moisture content (MC) of the joists was 10% and the perimeter band-joist 20%. The high MC of the band-joist was due to the house being so close to the ground and snow piling up along the outside of the house and saturating the base of the wall.

Exterior Wall/Ceiling Junction: Mold had begun to grow at the wall to ceiling junction several locations, primarily in the bedrooms (Figure 3). The interior temperature was approximately 70 to 74°F. The surface temperature of the wall in the field was 65°F, and the areas with mold measured 55°F. Interior relative humidity was 32% to 37%.

Building Research Council
Window Condensation and Damage:
Condensation, heavy enough to pool at the base of the glass and cause mold growth, occurred on several of the windows in the house (Figure 4).

Bathroom: Although surface mold was not present in the bathroom, mold probably had grown behind the plastic tub surround. Since the top surface of the tub’s pre-molded soap dish was missing, allowing a direct path for water into the exterior wall (Figure 5). Furthermore, the caulk sealing the base of the surround to the tub had separated thus providing another path for water into the walls (Figure 6).

The bathroom exhaust fan operated with a single-pole switch and moved approximately 25 to 28 CFM.

Attic Conditions: A hatch in a bedroom closet adjacent to the bathroom provided access to the attic. Moisture condensation and ice on the bottom of the roof sheathing, frost on roofing nails and moisture on top of the blown-in cellulose insulation were immediately evident (Figure 7). The moisture was worst in the area above the bathroom. There was no obvious connection of the bathroom fan to a roof jack. The bath fan was possibly blowing moisture into the attic. Moisture content (MC) of the roof sheathing measured 18%, the truss 5%, and the insulation 10%.

Another potential source of moisture was through the gable-end vents. The louvers of the vents did not appear to have much shielding potential against a driving rain or wind-blown snow (Figure 8).
Kitchen: The kitchen exhaust fan above the stove was a recirculation type fan and was not vented to the exterior.

Occupant Notes: Three non-smokers lived in the residence. One resident had recurring sinus problems and had recently suffered several bouts of pneumonia.

Recommendations: Three minor building modifications could very well resolve the wet crawl space conditions:

1. Install gutters on both the front and back of the house with leaders directing the water away from the house. See Section 4.1.
2. Install a vapor barrier on the crawlspace floor.
3. Remove the fiberglass crawl space wall insulation; replace it with 1 1/2" to 2" thick rigid polystyrene insulation.

Bathroom recommendations include:

1. Completely remove the current tub surround and damaged wall sheathing and insulation. Clean up mold according to New York City (NYC) and Environmental Protection Association (EPA) Guidelines, <http://www.epa.gov/iaq/molds/mold_remediation.html>. Dry and clean the wall cavities before reinsulating and covering with a vapor barrier. Then cover the wall with a moisture impermeable layer such as dens-shield and then install a new tub surround using a high quality caulk on joints.
2. Replace the fan with a high quality bath fan that moves substantially more air than the existing unit. See Section 4.4.
3. Interconnect the fan switch with the ceiling light and install a timed delay device.

Recommended attic modifications include:

1. Improve attic insulation. The mold at the wall to ceiling junction is due to the lack of attic space to properly insulate this area. See Section 4.3.
2. Connect the fan to the roof jack and seal at both ends.
3. Install a cover at the gable-end vents that allows the vent to breath, but does not allow blowing snow or rain to enter. Many houses in the neighborhood had such a protective cover, but this home did not.
4. Distribute the cellulose insulation evenly across the attic, and attach rigid insulation to the attic hatch topside.
5. Install dams to hold back the cellulose insulation and keep it in place around the attic access hatch.

Suggestions for other building improvements:

1. Replace the existing recirculation exhaust fan in the kitchen with an exhaust fan that vents to the exterior. Although the existing fan may mitigate odors, it does not remove the moisture from cooking.

2. The existing drier vent appears to be constricted (Figure 9). Install flexible ductwork without sharp bends. Terminate the vent in a wall jack with a backdraft damper.

3. Regularly replace the furnace filter. Dirty filters reduce the amount of airflow through the system, which contributes to poor air circulation in interior spaces. Poor circulation in interior spaces can lead to cool surface temperatures, which can lead to condensation and mold.

4. Eliminate the humidifier in the kitchen. Mold needs moisture to grow and adding moisture to the air can exacerbate an existing mold problem.
Appendix B, Fort Belknap Indian Community Housing Department
Technical Housing Assessment Report

March 5, 2003

Inspection Number: 1-2
Address: Unknown
Model Type: Frame Ranch
Age: About 30 years old
Bedrooms: 3
Foundation: Concrete block crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Cellulose Insulation

Mold and Moisture Conditions:
This home had mold at the wall to ceiling junctions, at the base of walls, in the bathroom, and in the crawl space.

Rainwater Management: The site was relatively flat. There was no roof drainage system (gutters, downspouts, etc.).

Crawl Space Conditions: The house was built on a concrete block crawl space very low to the ground. There was insufficient foundation height for installing crawl space vents in the concrete block wall therefore they were installed in the band joist. The crawl space was wet. The block was insulated with spray-on foam insulation (Figure 2). The foam surface was very uneven and rough, appearing to have mold growing on its surface at several locations. The water source for the mold could have come from either the crawl space floor, since it did not have a vapor barrier, or the exterior.

Although the crawl space floor was damp, the Moisture content (MC) readings of the joists were so low that they did not register on the moisture meter. The crawlspace with construction debris sitting directly on the soil had a MC of 10% (Figure 3). A disconnected drier duct contributed to moisture in the crawlspace (Figure 4). A piece of OSB screwed to the outside wall covered the drier exhaust portal.
Appendix B, Fort Belknap Indian Community Housing Department
Technical Housing Assessment Report

Exterior Wall/Ceiling Junction: Mold had begun to grow at many of the wall to ceiling junctions (Figure 5). The interior temperature was approximately 68°F. The surface temperature of the exterior wall in the field was 64°F; the areas with mold measured 58°F. Interior relative humidity was 20 to 25%.

Exterior wall: Some mold grew at the base of the wall at an exterior corner in one bedroom (Figure 6). The exterior sheathing on this corner was damaged and allowed moisture and air infiltration into the house (Figure 7).

Window Condensation and Damage:
Since the unit was empty, human activities did not contribute to interior humidity. As a result, the interior relative humidity was reasonably low with no condensation on the windows.

Bathroom: Surface mold was present along the perimeter of the bathtub ledge and the wall above the bathtub (Figure 8). The fan did not work (Figure 9). The area between the tub and the toilet near the base of the wall was badly deteriorated (Figure 10).
Attic Conditions: A hatch in a bedroom closet allowed access to the attic. The hatch had mold growth on its bottom side, and was not insulated on its topside (Figure 11). There was moisture condensation on the bottom of the roof sheathing and frost on the roofing nails sticking through the sheathing (Figure 12). The Moisture Content (MC) of the roof sheathing and top chord of the roof truss measured 20%. There was no visible mold present.

Kitchen: The bottom of the kitchen sink base cabinet was missing (Figure 13). A supply air outlet, which should vent out the face of the toekick if a base to the cabinet had been present, was revealed.

Occupant Information: The house was vacant.

Recommendations: Building modifications include:

1. Install gutters on both the house front and back with leaders directing the water away from the house. See Section 4.1.

2. Install a crawl space floor vapor barrier.

Bathroom modifications include:

1. Completely remove the current tub surround and area behind the toilet. Remove damaged wall sheathing and insulation. Clean up the mold according to New York City (NYC) and Environmental Protection Association (EPA) guidelines (See Section 6). Dry and clean the wall cavities before reinsulating and covering with a vapor barrier. Cover the walls with a moisture impermeable layer such as Dens-Shield and then install a new tub surround. Caulk with a high quality caulk at any joints.
2. Replace the inoperable bathroom fan with a high quality bathroom fan that moves at least 80 CFM. See Section 4.4.

3. Interconnect the fan switch with the ceiling light and install a timed delay device.

Recommended attic modifications include:

1. Improve the attic insulation. The mold at the wall to ceiling junction is due to the lack of attic space to properly insulate this area. See Section 4.3 for a way to improve this condition.

2. Connect the fan and the roof jack and seal at both ends.

3. Evenly distribute the cellulose insulation across the attic and attach rigid insulation to the topside of the attic hatch.

4. Install dams to hold back the cellulose insulation and keep it in place around the attic access hatch.

This house was generally in very poor condition on both the interior and exterior. Holes in walls and doors, missing floor tile, damaged cabinets, and more needed attention. On the exterior, the fiberboard sheathing was at the end of its useful life and needs replacement. Although salvageable, the house would require an investment of time and money to refurbish it to a habitable condition.
Appendix B, Fort Belknap Indian Community Housing Department
Technical Housing Assessment Report

Inspection Number: 1-3
Address: Unknown
Model Type: Frame Ranch
Age: About 30 years old
Bedrooms: 3
Foundation: Concrete block crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Fiberglass Batt Insulation

Mold and Moisture Conditions: This home had mold at the wall to ceiling junctions, at the base of walls, and in the bathroom.

Rainwater Management: The site was relatively flat with no roof drainage system (gutters, downspouts, etc.). The residents stated that during wet periods water stood around the house and in the crawl space.

Crawl Space Conditions: The house was built very low to the ground on a concrete block crawl space. There was insufficient foundation height for crawl space vents in the concrete block wall therefore they were installed in the band joist. The crawl space was wet. The block was insulated with eight-inch wide by ⅝ inch thick fiberglass strips glued to the block (Figure 2). Some strips had come loose and separated from the block, exposing a wet surface on the face of the block. Although not evident, the conditions existed for mold to flourish. The crawl space did not have a vapor barrier on the floor and the ground was damp.

Exterior Wall/Ceiling Junction: There were several locations of mold at the wall to ceiling junctions. The interior temperature was approximately 70°F, and interior relative humidity was 47%. The surface temperature of the exterior wall in the field was 68°F, but above the kitchen cabinets, the area of the worst mold growth, measured 58°F (Figure 3). The mold seemed to be the width of a space between ceiling framing members.

There were several areas that had mold at the wall to ceiling junctions (Figure 4).
Exterior wall: There was some mold growth at the base of the wall at an exterior corner in one bedroom (Figure 5).

Window Condensation and Damage: The interior relative humidity was quite high at approximately 47%. Several windows had condensation. Repeated wetting due to condensation had caused varied degrees of deterioration with mold growing on the lower horizontal rail of each sash (Figure 6). Due to the high interior humidity and the leakiness of the windows, there were ice flows at two windows. The outer windowpane was broken and ice had at the bottom left hand corner of the window (Figure 7). An adjacent bedroom window also had ice forming at the base (Figure 8).

Bathroom: The base of the wall between the bathtub and toilet was badly deteriorated (Figure 9). Repeated wetness caused the drywall to mold and deteriorate. The seal between the bathtub and plastic surround was breached and appeared to have been for quite some time by
the signs of water leakage into the wall (Figure 10).

The ceiling in the north bathroom sagged so much that it appeared as if the drywall was separating from the ceiling framing.

The fan in one bathroom moved 20 CFM of air and the fan in the other bath did not work.

**Attic Conditions:** Access to the attic was through a hatch, not insulated on the topside, in a hall closet. There was moisture condensation on the bottom of the roof sheathing and frost on the roofing nails sticking through the sheathing (Figure 11). The Moisture Content (MC) of the roof sheathing measured 25%. There was no visible mold present.

A return air register had recently been installed in the living room (Figure 12). After installation, insulation had not been replaced around the housing in the attic. The duct connecting the RA to the mechanical system was left long and snaked around the attic rather than cut to the proper length.

**Occupant Notes:** The house had six occupants, two parents and four children. The mother said the children had chronic respiratory problems which seemed to clear up if they left the house for a few days. There were smokers in the house.

**Recommendations:** At the ceiling mold was well embedded in the popcorn finish, which was difficult to clean due (Figure 13). Removing the rough texture and painting with high-quality paint would increase the cleanability of the ceiling surfaces.

Although difficult to discern with snow on the ground, the home appeared to be built in a low spot. Site drainage needed further study at a more appropriate time of year. Other minor building
modifications that would assist in helping resolve the wet crawl space conditions:

1. Install gutters on both the front and back of the house with leaders directing the water away from the house. See Section 4.1.

2. Install a vapor barrier on the crawl space floor.

Recommended for the bathroom include:

1. Completely remove the current tub surround, area behind the toilet and any damaged wall sheathing and insulation. Cleaned up the mold according to New York City (NYC) and Environmental Protection Association (EPA) guidelines see Section 6. Dry and clean the wall cavities before reinsulating and covering with a vapor barrier. Covered the wall with a moisture impermeable layer such as Dens- Shield and then install a new tub surround. Use a high quality caulk on the joints.

2. Replace both bathroom fans with a high quality bathroom fan that moves at least 80 CFM. See Section 4.4.

3. Interconnect the fan switch should be with the ceiling light and add a timed delay device.

4. Repair the sag in the bath ceiling.

Recommended attic modifications include:

1. Improve the attic insulation. The mold at the wall to ceiling junction was due to the lack of attic space which did not allow adequate insulation of the area. See Section 4.2 for a way to improve this condition.

2. Connect the fans to the roof jack and seal at both ends.

3. Evenly distribute the cellulose insulation across the attic and attach rigid insulation to the topside of the attic hatch.

4. Install dams to hold back the cellulose insulation and keep it in place around the attic access hatch.

1. Suggestions for other building improvements:

Replace the fiber-impregnated board on the house exterior. In many locations it extended into the snow allowing the siding to wick moisture into the structure through capillary action.
2. Routinely replace filters behind the return-air grill (Figure 14). Dirty filters reduce the amount of airflow through the system and contribute to poor air circulation in interior spaces. Poor circulation in interior spaces can lead to cool surface temperatures, a cause of condensation and mold.

3. The return air ductwork connecting the furnace to the ductwork penetrated the ceiling structure and was duct taped together (Figure 15). Duct tape is a poor material to use to seal ductwork. It dries out over time and separates from the materials it is meant to seal. Use specialized metallic tapes made for sealing ductwork.

4. The base of the cabinet beneath the kitchen sink is deteriorating and collapsing. This is also the location of a supply air duct. Clean and repair the base of the cabinet and install a new grill on the face of the toekick (Figure 16).
Inspection Number: 1-4
Address: Unknown
Model Type: Frame Ranch
Age: About 30 years old
Bedrooms: 3
Foundation: Concrete stem wall crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Fiberglass Batt Insulation

Mold and Moisture Conditions: Although this home had minor areas of mold growth, more evident were past instances of heavy condensation at the top of exterior walls and liquid water stains running down the walls (Figure 2).

Rainwater Management: The site had positive drainage away from the structure and there were no roof drainage system (gutters, downspouts, etc.).

Crawl Space Conditions: The crawl space vents were installed in the band joist. The crawl space had a well-installed vapor barrier over the soil. The soil beneath the barrier was wet (Figure 3).

One corner of the crawl space had an approximately two and one-half foot deep sinkhole in it (Figure 4). At that time the footing had not yet been undermined, however the cause of the sinkhole was unknown.

15 lb. roofing felt was attached to the crawl space walls. Expanded polystyrene filled in tight to the plywood sheathing between some joists (Figure 5). Minor debris was present.

Building Research Council
Exterior Wall/Ceiling Junction: The bathroom and kitchen had instances of mold at the wall to ceiling junction (Figure 6). The interior temperature was approximately 71°F, and interior relative humidity was 37%. The surface temperature of the exterior wall in the field was 70°F, with the area of mold growth above the kitchen corner cabinet measuring 58°F (Figure 7).

Bathroom: Other than minor mold, the biggest problem in the bathroom was a missing bathroom fan (Figure 8). The housing was present, but the fan motor had been removed. According to the owner the fan housing occasionally leaked water and ruined the fan.

Attic Conditions: Access to the attic was through a hallway hatch, insulated on its topside and heavy to lift. There was moisture condensation on the bottom of the roof sheathing, particularly in the area above the bathroom with the missing fan (Figure 9). The Moisture Content (MC) of the roof sheathing above the bathroom measured 23%, and 15% in the dry areas. The insulation was unevenly distributed (Figure 10) and the insulation seemed to be shoved up tight to the roof sheathing at the end of the trusses thus not allowing sufficient ventilation to occur. If allowed to continue, the sheathing will slowly rot away.

Exterior Siding: The fiber-composition-board siding with a finish impregnated on its face had reached the end of its service life. Overlaps at seams
were not tight and many edges and corners of the boards were damaged. Water and air could enter the structure at the damaged areas (Figure 11). The drier vent cap was missing (Figure 12), allowing cold air to blow into the vent and back toward the drier. The duct in the crawl space had frost on it.

**Occupant Information:** The house had six occupants, two parents and four children. The father said that the children had chronic respiratory problems. There were no smokers in the house.

**Recommendations:** Install gutters on both the front and back of the house with leaders directing the water away from the house. See Section 4.1.

Replace the furnace filter and install a new one after checking that the coils are not clogged with dust.

Bathroom recommendations follow:

1. Replace bathroom fans with high quality bathroom fans that moves at least 80 CFM. See Section 4.4.
2. Interconnect the fan switch with the ceiling light and install a timed delay device.

Recommended attic modifications include:

1. The staining at the wall to ceiling junction is due to the lack of space in the attic for sufficient and proper insulation. This area gets colder than the rest of the wall, thus during periods of high humidity, water vapor condenses at this location and runs down the wall. See Section 4.3 for a way to improve this condition.

2. Connect the fans to the roof jack and seal at both ends.

3. Distribute the fiberglass insulation evenly across the attic.

4. Install ventilation baffles between the ends of the trusses so that air entering eave vents can migrate up into the attic space and wick moisture out of the attic space.

Exterior improvements should include:

1. Remove and replace siding.
2. Install a new air barrier beneath the siding.
3. Install a new drier vent cap.

While the siding is off of the wall, consider installing additional foam insulation beneath the siding, and replacing all of the double hung windows with higher quality units.
Appendix B, Fort Belknap Indian Community Housing Department
Technical Assessment Report

Inspection Number: 1-5
Address: Unknown
Model Type: Modular Home
Age: Two years old
Bedrooms: 3
Foundation: Concrete stem wall crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Inaccessible

Mold and Moisture Conditions: This home had minor mold growth on the wall behind where the washing machine would have set (Figure 2).

Rainwater Management: The site had positive drainage away from the structure, and there is no roof drainage system (gutters, downspouts, etc.).

Crawl Space Conditions: The crawl space had a fairly well installed vapor barrier on top of the soil (Figure 3). The soil beneath the barrier was wet. One crawl space vent was open to the exterior allowing cold air to blow in (Figure 4).

Bathroom: Maintenance staff working on the house said that there had been some minor mold along the baseboard in the common bathroom, but the area had been cleaned up and repainted.

Attic Conditions: This was a modular home and the attic was sealed and inaccessible.

Utility/Mechanical Room: The rear entry was through a utility room off the kitchen. The utility room had space for a washer and drier and also housed the mechanical system and electrical panel. Mold was present on the wall where the washing machine would have sat. It was minor and could have been due to a leaking washing machine connection. For some undisclosed reason the wall had been opened up.

The mechanical system was a high efficiency propane gas unit.
The condensate drain for the system drained directly into the crawl space (Figure 5).

The inside face of the electrical panel cover had an Energy Star Good Cents sticker listing the R-values of the roof, floor, and wall sections (Figure 6). A hole in the siding on the outside of the structure allowed the team to examine a cross section of the wall assembly. There was drywall on the interior, 2x6 wall framing with fiberglass insulation between studs, and a cementations type siding. The R-value of 33 for the wall section was questionable. Based on the team’s observations, the wall section was not nearly what the Good Cents sticker stated.

**Exterior Siding:** Although the house was only two years old, the exterior siding was damaged. The siding was a thin, approximately 3/8 inches thick, cementations type siding and was damaged at the corner (Figure 7).

**Occupant Information:** The home was vacant at the time of inspection.

**Recommendations:**

1. Install gutters on both the front and back of the house with the leaders directing the water away from the house. See Section 4.1.

2. Extend the condensate drain for the heating system to the exterior of the house.

3. The thermal boundary in these modular homes is the floor system rather than the crawl space walls. Since the crawl space is thermally separated form the living space, it can get quite cold. Therefore, it is important to close the crawl space vents during the winter months. Cold air allowed into the crawlspace could freeze plumbing waste and supply lines.
Inspection Number: 1-6
Address: Unknown
Model Type: Modular Home
Age: Two years old
Bedrooms: 3
Foundation: Concrete stem wall crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Inaccessible

Mold and Moisture Conditions: This home had minor mold growth in the bathroom above the tub area (Figure 2).

Rainwater Management: The site had positive drainage away from the structure and there was no roof drainage system (gutters, downspouts, etc.).

Crawl Space Conditions: The crawl space in this unit was not inspected, because occupant possessions filled the closet in which the crawl space access hatch was located.

Bathroom: Mold was present at the wall to ceiling junction above the bathtub (Figure 2).

Windows and Doors: Windows and doors in this and all the other 2-year old units were being replaced. The windows apparently leaked air profusely during windy conditions. The existing metal frame, double-pane windows were being replaced with wood frame double-pane windows (Figure 3).

Attic Conditions: This was a modular home and the attic was sealed and inaccessible.

Occupant Notes: Although occupant possessions were present, the occupants were unavailable at the time of inspection.
Recommendations:

1. Gutters should be installed on both the front and back of the house and the leaders should direct the water away from the house. See Section 4.1.

2. Mold in the bathroom should be cleaned up with soap and water.

3. Regular replace dirty electric furnace filters (Figure 4). Dirty filters reduce the airflow through the system, contributing to poor air circulation in interior spaces. Poor circulation in interior spaces can lead to cool surface temperatures, a cause of condensation and mold.

4. Keep the area around the crawl space hatch clear to facilitate inspection. Regularly inspect the duct connecting the air handler to the trunk duct on the other half of the modular unit. Check the condensate drain to make sure it drains to the exterior.
Appendix B, Fort Belknap Indian Community Housing Department
Technical Assessment Report
March 5, 2003

**Inspection Number:** 2-1  
**Address:** Unknown  
**Model Type:** Frame Modular Ranch  
**Age:** Two years old  
**Bedrooms:** 3  
**Foundation:** Concrete stem wall crawl space  
**Heat Type:** Gas forced air  
**Construction:** Wood framed  
**Attic:** Inaccessible  

**Mold and Moisture Conditions:** This home had minor mold growth in the master bathroom at the bottom of the wall behind the toilet (Figure 2).

**Rainwater Management:** The site was close to the bottom of a watershed and does not have positive drainage away from the structure. There was no roof drainage system (gutters, downspouts, etc.).

**Crawl Space Conditions:** A vapor barrier covered the crawl space floor. A footing running longitudinally the length of the building divided the crawl space floor. One-half of the crawl space floor area had a 3/16" layer of dirt on top of the VB (Figure 3). The trunk duct that supplied the ducts in the front half of the building were disconnected (Figure 4). The HVAC condensate line drained into the crawl space. The footing was undermined at the building drain exit (Figure 5).

**Bathroom:** Minor mold growth in the master bathroom was at the bottom of the wall behind the toilet. Both bathrooms had working fans. Airflow for the master bathroom measured 25 CFM and for the common bathroom measured 28 CFM.

**Windows and Doors:** Windows had been replaced in this unit but had not yet been trimmed out on the interior.
Attic Conditions:  This was a modular home with a sealed and inaccessible attic.

Occupant Notes:  There were four occupants in this home, two adults and two children. One child had asthma.

Kitchen:  The caulk joint between the tile backsplash and the kitchen countertop has dried out and separated (Figure 6). This allows water to seep beneath the tile where it can pool, eventually rot the drywall and possibly damage the countertop. Also, mold may grow.

Recommendations:

1. Occupants stated that during the past spring the crawl space had almost completely filled with water, and that there was a large pond of water in front of the residence. The team theorized that the pool of water in front of the residence drained through the undermined footing and washed dirt over the front half of the crawl space. A culvert had not been installed in front of the residence to alleviate the flooding problem. The snow covered ground prevented inspection of the terrain. The flooding problem needed to be resolved.

2. The residents stated the toilet in the master bathroom leaked and that installation of multiple wax seals had failed to stop the leaking, which probably contributed to the mold forming at the vinyl cove base behind the toilet. Remove the toilet and mount the plumbing flange at the proper height to eliminate the need for multiple wax seals. Cleaned with soap and water and allow the area to dry out before replacing the cove base.

3. Remove the existing caulk between the kitchen backsplash and the countertop and reseal the seam with a high quality silicone caulk.

4. Repair damaged exterior siding promptly before water can infiltrate wall cavities (Figure 7).

5. Install gutters on both the front and back of the house with the leaders directing the water away from the house. See Section 4.1.
Inspection Number: 2-2
Address: 1417 Azalia Street
Model Type: Frame Ranch
Age: About 30 years
Bedrooms: 2
Foundation: Concrete block stem wall crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Not inspected

Mold and Moisture Conditions: This home had significant mold growth in the bathroom and kitchen.

Rainwater Management: The site at the front of the house sloped down towards the structure, and at the rear of the house the slope continued away from the house. Gutters and downspouts were present, but the downspout at the front of the structure was completely crushed flat at its midpoint, and the rear downspout was also partially crushed (Figure 2).

Crawl Space Conditions: A vapor barrier covered the crawl space floor. Inspection disclosed a disconnected supply duct to the front bedroom (Figure 3). In several locations there was evidence of water damage to the plywood subfloor beneath the bathroom (Figures 4 & 5). The crawl space was used as additional storage space.
Bathroom: There was significant mold growth in the bathroom above the tub area on the walls and ceiling (Figure 6). The bathroom fan worked, but only moved 28 CFM. There was evidence that the bath valve leaked (Figure 7).

Windows and Doors: Several windows had mold growth on the sash and frame. The bottom portion of the window sash of above the kitchen sink was consumed by mold (Figure 8). The glass above the sash was covered with a sheet of ice. The bedroom window also had significant mold (Figure 9).

Attic Conditions: Inspectors could not access the attic. Based on the findings in the bathroom, it was probable that a marginal amount of insulation was present.

Occupant Information: Although the home usually had two occupants, there were six at the time of the site visit. One child in the home was asthmatic.

Interior Conditions: The interior temperature in the living room/kitchen area was 67°F and relative humidity was 37%. The bedroom with the disconnected duct was slightly cooler at 64°F, with a surface temperature of 54°F at the upper corner where mold had formed at the wall to ceiling (Figure 10). Surprisingly the interior relative humidity was not high, since cloths were hung indoors to dry.
Drier: Based on the lint found behind the drier, the team suspected that the drier vent might have been compromised (Figure 11).

Recommendations:

1. The mold in the bathroom was due to a combination of factors: inadequate attic insulation was probably one factor, the fan not moving enough air was another, as was the casual approach to housekeeping. First, resolve the fan and insulation problem, secondly, clean up the mold.

2. Replace the kitchen window, which is beyond repair.

3. Reconnect the supply air duct to the front bedroom. Remove the items covering the register in order to allow heat to move through the register and into the front bedroom.

4. Pull the drier away from the wall in order to inspect and fix it, if needed. Repairs would reduce the lint problem.

5. Replace the living room broken window (Figure 12).

6. Replace the downspouts.
Inspection Number: 2-3
Address: 1606 Azalia Street
Model Type: Frame Ranch
Age: About 30 years
Bedrooms: 3
Foundation: Concrete block stem wall crawl space
Heat Type: Electric baseboard
Construction: Wood framed
Attic: Not inspected

Mold and Moisture

Figure 2: Bath corner
Figure 3: Crawlspace w/residue on top of VB
Figure 4: Leaky toilet flange

Conditions: Although this home had only minor mold problems, the residents reported significant bathroom in the past (Figure 2).

Rainwater Management: The house had positive drainage away from the building, however, according to the occupants, the crawl space gets wet in the spring due to snow melt. It appeared that a roof valley would deposit water next to the foundation and contribute to the wet crawl space. There were no gutters on the house.

Crawl Space Conditions: A vapor barrier covered the crawl space floor. Significant residue on top of the VB indicated past instances of water on top of it (Figure 3). Inspection disclosed evidence of water damage to the plywood subfloor beneath the toilet flange (Figure 4). There was a drop of water on the waste pipe beneath the toilet flange indicating a leaky toilet seal. The crawl space was being used as additional storage space.

Bathroom: The occupants stated that in the past, there had been some bad mold problems on the exterior wall above the bathtub. Maintenance had removed the drywall and insulation, reinsulated and replaced the wallboard. According to the occupants, mold on the interior of the wall was not cleaned before it was rebuilt. Without destructive
testing, it would be impossible to examine the interior of the wall. However, if the water source was eliminated any remaining mold should go dormant. The bathroom exhaust flow was 28 CFM.

**Attic Conditions:** The team did not inspect the attic as there was no ladder. However, several locations at the wall to ceiling junction showed evidence of water staining on exterior walls (Figure 5). This was undoubtedly due to incidents of high interior humidity, cold exterior conditions, and marginal insulation at this location. Staining rather than mold growth indicates no chronic problem.

**Occupant Notes:** Occupants complained of respiratory problems. Occupants maintained a clean residence and mold would only become a problem where insulation was lacking or had been compromised, and allows water to condense persistently.

**Interior Conditions:** The interior temperature was 71°F, and interior relative humidity was 35%. There was a large fish tank in the residence, but it did not seem to contribute excess moisture to the interior environment.

**Recommendations:**

1. Resolve the drainage problems into the crawl space by regrading the site near the front entry.

2. Increase and baffle the insulation along the perimeter of the attic to keep cold air as distant from the interior corner as possible. This should reduce the incidence of water condensation and staining along the interior wall to ceiling junction.

3. Monitor the bathroom for any incidence of mold growth, and check the toilet for leakage and reseat.
Inspection Number: 2-4
Address: 1602 Mayor Drive
Model Type: Frame Ranch Duplex
Age: Approximately 30 Years
Bedrooms: 3
Foundation: Concrete block stem wall crawl space
Heat Type: Gas forced air
Construction: Wood framed
Attic: Not inspected

Mold and Moisture Conditions: This home had extensive mold problems.

Rainwater Management: The house had positive drainage away from the building. There were no gutters on the house.

Crawl Space Conditions: The team did not have a ladder and thus inspected the crawl space from the hatch. The crawl space was full of debris. It appears that only a portion of the crawl space had a vapor barrier (VB). There was mold on the debris in the crawl space. Watermarks on the waste piping indicate leaking plumbing.

Bathroom: The bathroom had mold above the bathtub (Figure 2). The base of the wall next to the plumbing end of the tub had a hole. The bathroom fan did not function (Figure 3). The vanity sink was stained. The toilet was not sealed tightly to the floor and easily rocked side-to-side.

Attic Conditions: Due to the unavailability of a ladder, the attic was not inspected.

Kitchen: The kitchen had extensive water staining on the ceiling (Figure 4). The window had mold on it, and most of the cabinet drawers were missing.
The sink trap must have had a leak because duct tape seals two joints (Figure 5).

**Bedrooms:** The bedrooms had mold on the ceilings, walls, and in closets (Figure 6 & 7).

**Occupant Notes:** There was a mother and two children, one with asthma, in the home.

**Interior Conditions:** The interior temperature was between 65°F and 68°F. Interior relative humidity was between 28% and 32%.

**Recommendations:** This home was in poor condition and requires extensive work.

1. Thoroughly clean the house to identify surfaces which need remediation.
2. Clear all debris out of the crawl space and install a vapor barrier over the soil.
3. Check all bathroom plumbing for leaks, and repair the bathroom fan.
4. Repair the kitchen sink trap.
5. Repair the broken window and holes in walls in the living room (Figure 8 & 9).
6. Check the adequacy of the attic insulation levels. Based on water stains on the ceiling, there have probably been incidents of excessive high humidity in the residence, and cold ceiling surfaces due to marginal insulation levels.
7. Finally, include both occupants and counselors in the solving of housing problems. Training and education provided by counselors form an important training on lifestyle modification.
Inspection Number: 2-5  
Address: 1608 Azalia Street  
Model Type: Frame Ranch Duplex  
Age: Approximately 30 Years  
Bedrooms: 3  
Foundation: Concrete block stem wall crawl space  
Heat Type: Gas forced air  
Construction: Wood framed  
Attic: Not inspected  

Mold and Moisture Conditions: This residence had some mold, but was not in bad condition.

Rainwater Management: There were no gutters on the home. Due to the snow on the ground, assessing the exact grade adjacent to the home was difficult, but it appeared to slope away from the residence.

Crawl Space Conditions: The team did not have a ladder and thus inspected the crawl space from the hatch. The crawl space had some debris (Figure 2). Remnants of a vapor barrier were present but most of the crawl space was exposed soil. It appeared there had been water in the crawl space in the past. Watermarks on the waste piping evidenced past and/or present leaking plumbing (Figure 3).

Bathroom: The bathroom vanity base cabinet had mold and the base was badly deteriorated (Figure 4). The bathroom exhaust fan flow rate was measured at 47 CFM.

Attic Conditions: Due to the unavailability of a ladder, the attic was not inspected.

Kitchen: The kitchen exhaust fan was vented to the exterior.
Bedrooms: There was no apparent mold in the bedrooms. However, belongings abandoned by the previous tenants covered the bedrooms floors (Figure 5).

Occupant Notes: This unit had been vacant for five to six months. Clothes and debris were strewn over the floors. It was difficult to move without stepping on abandoned occupant debris.

Recommendations:

1. Remove and replace the bathroom vanity and repair the surrounding walls at the same time.

2. Remove all occupant belongings and clean the house thoroughly.

3. Install a new hot water heater replacement for the missing one.

4. Remove all the crawl space debris and the crawl space floor with a vapor barrier.

5. Clean the return air grill and replace the filter (Figure 6).