US Army Corps
of Engineers
Omaha District

Nonstructural Flood Damage Reduction Assessment for Kaycee, Wyoming

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Prepared by
U.S. Army Corps of Engineers
Omaha District

Nonstructural Flood Damage Reduction Assessment

A nonstructural flood damage reduction assessment was conducted for the Town of Kaycee, Wyoming. The flood of August 27, 2002 caused considerable damages to the community and its residents. As a means to eliminate or reduce future flood damages within the community, this assessment investigated the feasibility of implementing nonstructural measures for individual buildings.

For this assessment, nonstructural measures are defined as modifications incorporated into the design, construction, or alteration of individual buildings or properties that will reduce flood damages. In general, nonstructural flood proofing includes any effort property owners may take to reduce flood damages to buildings and their contents.

Flood Damage Reduction

The potential for flood damages to occur is determined by the depth of flooding and the frequency in which a building and its contents may be flooded. Flood proofing a building will decrease the potential for damage from future floods. Without flood proofing, a building is subject to damage from all floods that enter the lowest elevation of the building or rise above the first floor elevation. With flood proofing techniques such as raising a building, floodwaters must rise to a higher elevation to cause damage.

Flood proofing can benefit the property owner in several ways. It will save money that would otherwise be spent to repair and clean the exterior and interior of the building as well as reducing the expense of replacing building contents. Also, damage prevented by flood proofing will reduce the inconvenience and annoyance caused by the time-consuming process of cleaning up and repairing a building.

Effectiveness

The only method of flood proofing that will ensure complete safety from flood damage is relocating the building to a site outside of the flood plain. When buildings are not removed from the flood plain, floodwaters may rise to an elevation that overcomes flood proofing measures causing even greater damages than would have been caused without flood proofing. Unless a building is relocated out of the flood plain, the building will still be exposed to some potential flood damage even if flood proofed.

Safety

Even after flood proofing, a building in a flood-prone location will still be subject to flooding if floodwaters overtop the flood proofing measures or if failure of the system occurs. Property owners must keep this in mind in order to avoid a false sense of security. No one should remain in such a building during a flood. High velocity flows, waves, debris, or other conditions can cause floodwaters to suddenly overtop the flood proofing measures, leaving occupants little or no time or ability to vacate the building and flooded areas. In addition, rising floodwaters may restrict all methods or paths of egress during a flood. This is hazardous and life threatening.

Building Types

Some types of buildings are more suitable for flood proofing than others. The appropriate flood proofing methods will depend on the construction material of the building, such as brick or wood frame. Also the nature of the building's design, such as the number of floors, basements, slab foundations, or crawl spaces. It is essential to know the type of construction of the building when analyzing potential flood proofing methods. A building totally unsuitable for one flood proofing method may be effectively flood proofed by another method. A variety of flood proofing options should be considered before excluding a building as a candidate for flood proofing. Houses with basements, for example, generally provide a greater challenge to successful flood proofing.

Flood proofing may be designed to either reduce the number of times the building is flooded or limit the potential damage to the building and its contents when it is flooded. There are three general approaches this assessment considered for flood proofing:

- Raising (elevation) the building to a higher elevation
- Constructing barriers (dry flood proofing) to prevent floodwaters from entering
- Relocating the building and its contents out of the flood hazard area

Nonstructural Techniques Considered

Raising

Raising involves elevating the building in place so that the lowest damageable floor is located above the flood level for which flood-proofing protection is provided. The building is raised and set on a new or extended foundation.

Almost any structurally sound building can be elevated. Typically, the least expensive and easiest building to elevate is a one-story frame building built over a crawl space that is 18 inches or higher. The process becomes more difficult and expensive as different factors are added, such as a building with abasement, a slab-on-grade building, a building constructed of brick or block, a multi-story building, or building with additions.

Buildings can be elevated on several different types of foundations, including raised foundation walls or an open foundation. Elevating a building on an open foundation involves raising it onto piers, posts (columns), or piles. If the building is located in an area of coastal flooding, an open foundation is the only way to safely elevate. If the building is subject to high-velocity floodwaters, significant water depths, or potential erosion, the property owner should also consider having the building elevated on an open foundation. Doing so will allow the waters to flow beneath the building and reduce potential damaging impacts.

Relocation

Relocating a building is the most dependable, but generally the most expensive way to flood proof. This method involves moving the building to another location away from flood hazards, either to a higher elevation on the existing lot or to a new site. Relocating a building out of the flood plain is appropriate if the building is in an area where flood hazards are such that continued occupation is unsafe. It is also an option for the property owner who wants to be free from the damages, and worry associated with flooding.

Relocating a building involves the same procedure as raising a building, which is described in the previous section. After the building is raised, it is then transported to a new location and placed on a new foundation.

Property owners should consider many factors before deciding to relocate, including the building's structural soundness and whether there are bridges, power lines, or other obstructions located along the transportation route.

During the move, property owners and their families must live elsewhere, perhaps for several weeks, and may need to store furniture and belongings temporarily. In addition to paying the moving contractor, the property owner may need to purchase a new lot (if the owner is not staying on the present lot), build a new foundation, relocate utilities, landscape, and pay for professional services and fees.

Dry Flood Proofing

Dry flood proofing involves sealing the exterior side of building walls with waterproofing compounds, impermeable sheeting, or other materials and using shields for covering and protecting openings from floodwaters. In areas of shallow, low velocity flooding, shields can be used on doors, windows, vents, and other building openings. The first step with the use of shields placed directly on buildings is to be certain that both the shield and the building are strong enough and sufficiently watertight to withstand flood forces. Sewer lines should be fitted with cutoff or check valves that close when floodwaters rise in the sewer, to prevent backup and flooding inside the building.

Dry flood proofing is not generally recommended for buildings with a crawl space or basement, because these types of buildings are susceptible to under seepage, which can result in significant "uplift" or buoyancy forces and create serious design problems. Generally, dry flood proofing should only be employed on buildings constructed of concrete block or brick veneer on a wood frame. Weaker construction materials, such as a wood frame, will fail at much lower water depths from hydrostatic forces. Even brick or concrete block walls should not be flood proofed above a height of three feet, due to the danger of structural failure from hydrostatic forces.

Some waterproofing compounds cannot withstand significant water pressure or may deteriorate over time. For effective dry flood proofing, a good interior drainage system must be provided to collect the water that leaks through the sealant or sheeting and around the shields. These systems can range from small wet-vacs to a group of collection drains running to a central point from which water is removed by a sump pump. Property owners considering dry flood proofing should consult a professional engineer to analyze hydrostatic forces that can cause structural damage to walls and floors. Though dry flood proofing may seem simple, it is a sophisticated method that requires full understanding of the possible dangers stemming from poor planning, design, or installation.

Most wall materials, except for some types of high-quality concrete, will leak unless special construction techniques are used. These techniques require a high level of workmanship if they are to be effective. The most effective method of sealing a brick faced wall would be to install a watertight seal behind the brick when the building is constructed. For flood proofing existing buildings, the best way to seal a wall is to add an additional layer of brick with a seal "sandwiched" between the two layers. It is possible to apply a sealant to the outside of a brick or block wall, but any coating must be applied carefully. Cement or asphalt based coatings are the most effective materials for sealing a brick wall, while clear coatings such as epoxies and polyurethanes tend to be less effective. As a result, the aesthetic advantages of a brick wall are lost with the use of better sealant coatings.

The difficulty and complexity of sealing a building also depends on the type of foundation, since all structural joints, such as those where the walls meet foundations or slabs, require treatment. For very low flood levels, such as a few inches of water, a door can be flood proofed by installing a waterproof gasket and reinforcing the doorjamb, hinge points, and latch or lockset and coating it with a waterproof paint or sealant.

If there is a chance of higher flood levels, some type of shield will be needed. If the expanse across the door is three feet or greater, the shield will have to be constructed of heavy materials, such as heavy aluminum or steel plate. The resulting weight may require the shield to be permanently installed, using either a hinged or slide-in design. The frame for such an installation must be securely anchored into the building. When windows are exposed to flooding, some form of protection is needed because standard plate glass cannot withstand flood forces. One solution is to brick up all or part of the window. It may also be possible to use glass block, instead of brick, to admit light.

For normal-sized windows, shields can also be used. They should be made of materials such as heavy Plexiglas, aluminum, or framed exterior plywood. These can be screwed in place, or slid into pre-designed frame slots. Another alternative is to replace the glass with heavy Plexiglas; however, the window must be sealed shut and waterproofed using water resistant caulking.

Nonstructural Mitigation Cost Considerations

The values used for the unit costs in this assessment were obtained from several sources. Data developed by the Corps of Engineer's National Nonstructural Flood Proofing Committee during 1993 was updated using building cost index ratios provided by the Engineering News Record (ENR) for August 2004. Unit costs were also developed. The assessment included researching similar flood proofing measures that have been utilized in other regions of the country. Each assessment included an additional 25% contingency to cover unforeseen costs. The unit costs used for this nonstructural assessment are presented in Table 1.

Table 1
Nonstructural Assessment Unit Costs

Technique	Unit Cost ($)	
Raising		
Cost to Elevate **	26.60	Per square foot
Cost of fill/cubic Yard	14.00	Per cubic yard
Temporary Housing	2,200.00	Lump sum
** Includes foundation, extending utilities, and miscellaneous items, such as sidewalks and driveways. It does not include cost of fill or landscaping.		
Relocation		
Move Double-wide Trailer	7,500.00	Lump sum
Temp Storage	1,500.00	Lump sum
Cost of new lot plus utilities	30,000.00	Lump sum
Temporary Housing	2,200.00	Lump sum
Dry Flood Proofing		
Flood shield (Metal)	92.40	Per square foot
Pump	840.00	Lump sum
Spray on cement	4.20	Per square foot
Drain interior	39.20	Per linear foot
Plumbing check valve	840.00	Lump sum

Nonstructural Mitigation Assessment

For this assessment only six buildings were identified and investigated to determine if nonstructural mitigation would be feasible. The buildings that were investigated consisted of a commercial store, three one-story houses without basements, a mobile home, and a two-story house without basement. These were evaluated regarding the efficacy of nonstructural measures and for economic justification. Economic considerations included computation of a simple benefit cost ratio (BCR - ratio of flood control benefit to project cost) and a comparison of building and lot value to the cost of the measure. Nonstructural measures were deemed to be feasible if the benefits from the measure were equal too or greater than the cost (a BCR of 1.0 or greater) and the cost of the measure was less than the combined building and lot value. Figure 1 presents the location of each of the six buildings evaluated.

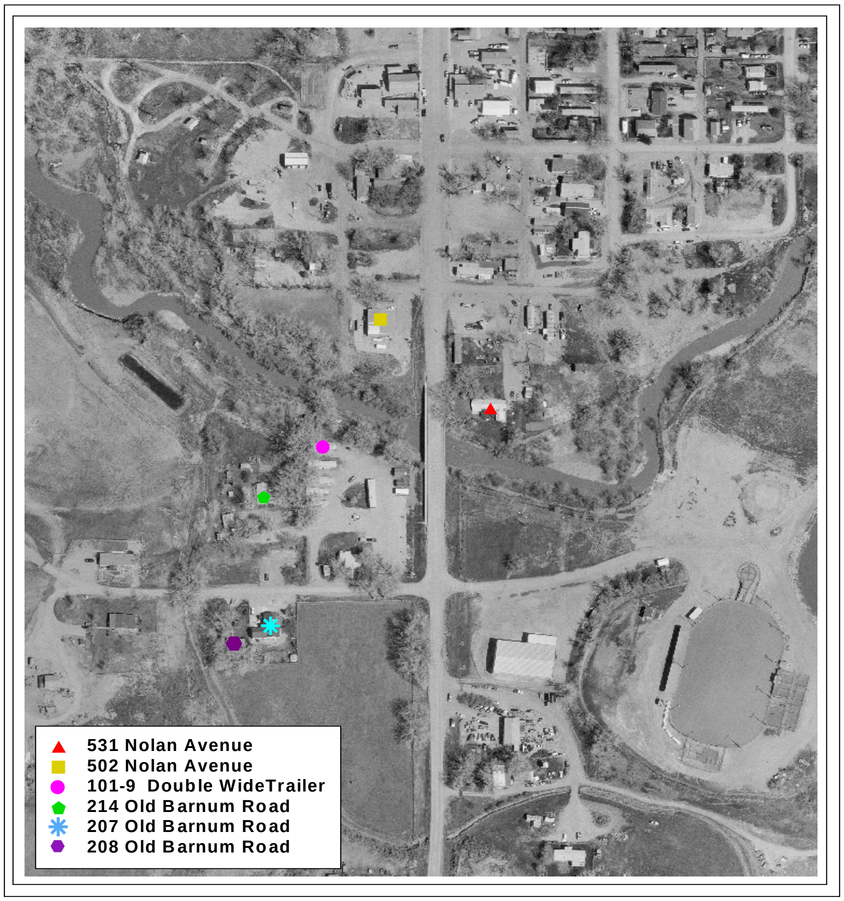

Figure 1
Location Map for Mitigation Measures

531 Nolan Avenue

The nonstructural measure for this building was raising it on site. The results of this assessment are shown in the table below.

531 Nolan Avenue	
Location ID#	25311
Building Type	One story w/o basement
Building and Lot Value:	$73,500
Ground Elevation	4601.7
First Floor Elevation	4602.2
100-Year Water Surface Elevation	4606.9
100-Year Depth of Flood	5.2
Estimated Annual Benefits	$16,694
Nonstructural Measure Evaluated	Elevate on fill
Total Estimated Cost	$98,653
Estimated Annual Cost	$6,694
Benefit to Cost Ratio of Measure	2.49

*Annualized over 30 year lifespan at 5.375%

Nonstructural flood proofing of this building would have a positive BCR. However, the measure is not considered to be feasible because its cost exceeds the combined value of the building and the lot (i.e. value of real estate being protected).

207 Old Barnum Road

The nonstructural measure for this building was raising it on site. The results of this assessment are shown in the table below.

207 Barnum Rd.	
Location ID#	32071
Building Type	One story w/o basement
Building and Lot Value:	$55,000
Ground Elevation	4603.8
First Floor Elevation	4604.6
100-Year Water Surface Elevation	4610.5
100-Year Depth of Flood	6.7
Estimated Annual Benefits	$11,449
Nonstructural Measure Evaluated	Elevate on fill
Total Estimated Cost	$89,189
Estimated Annual Cost	$6,052
Benefit to Cost Ratio of Measure	1.89

*Annualized over 30 year lifespan at 5.375%

Nonstructural flood proofing of this building would have a positive BCR. However, the measure is not considered to be feasible because its cost exceeds the combined value of the building and the lot.

208 Old Barnum Road

The nonstructural measure for this building involved raising it on site. The results of this assessment are shown in the table below.

208 Old Barnum Road	
Location ID#	32081
Building Type	One story w/o basement
Building and Lot Value:	$225,000
Ground Elevation	4605.3
First Floor Elevation	4606.3
100-Year Water Surface Elevation	4610.3
100-Year Depth of Flood	5
Estimated Annual Benefits	$22,222
Nonstructural Measure Evaluated	Elevate on fill
Total Estimated Cost	$91,206.89
Estimated Annual Cost	$5,288
Benefit to Cost Ratio of Measure	4.20

*Annualized over 50 year lifespan at 5.375%

214 Old Barnum Road

The nonstructural assessment for this building involved looking at raising the building on site. The results of this assessment are shown in the table below.

214 Barnum Road	
Location ID#	32141
Building Type	One story w/o basement
Building and Lot Value:	$95,000
Ground Elevation	4605.7
First Floor Elevation	4606.7
100-Year Water Surface Elevation	4610.6
100-Year Depth of Flood	5
Estimated Annual Benefits	$6,081
Nonstructural Measure Evaluated	Elevate on fill
Total Estimated Cost	$52,372.88
Estimated Annual Cost	$3,554
Benefit to Cost Ratio of Measure	1.71

*Annualized over 30 year lifespan at 5.375%

101-9 Mobile Home

The nonstructural assessment for this building involved looking at relocating. The results of this assessment are shown in the table below.

101-9 Double Wide Mobile Home	
Location ID#	31019
Building Type	One story w/o basement
Building and Lot Value:	$60,000
Ground Elevation	4604.4
First Floor Elevation	4606.4
100-Year Water Surface Elevation	4610.2
100-Year Depth of Flood	5.8
Estimated Annual Benefits	$5,560
Nonstructural Measure Evaluated	Relocation
Total Estimated Cost	$32,200
Estimated Annual Cost	$2,667
Benefit to Cost Ratio of Measure	2.08

*Annualized over 20 year lifespan at 5.375%

502 Nolan Avenue

The nonstructural assessment for this building involved looking at dry flood proofing. The results of this assessment are shown in the table below.

502 Nolan Avenue	
Location ID#	15021
Building Type	Commercial
Building and Lot Value:	$100,000
Ground Elevation	4607.4
First Floor Elevation	4607.4
100-Year Water Surface Elevation	4610.1
100-Year Depth of Flood	2.7
Estimated Annual Benefits	$1,899
Nonstructural Measure Evaluated	Dry flood proof
Total Estimated Cost	$21,600.00
Estimated Annual Cost	$1,466
Benefit to Cost Ratio of Measure	1.30

*Annualized over 30 year lifespan at 5.375%

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Summary of Results

The nonstructural assessment investigated the potential feasibility of flood proofing six different buildings for the community of Kaycee. The results indicate that it would be feasible to implement nonstructural measures such as raising, dry flood proofing, and relocation for four of these buildings. They include two single-family residences, a mobile home and a commercial building. The other two are not feasible because although each has a positive BCR (greater than 1.0), the investment cost of the flood control measure exceeds the combined building and lot value.

A detailed nonstructural analysis for all buildings located in the existing flood plain could identify additional buildings which would be feasible to flood proof singularly, or perhaps as small groups of two, three or four buildings, where low lying barriers could be implemented to benefit several buildings having low to moderate damage levels.