Community Guide for Flood Risk Reduction on Alluvial Fans

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Cover photo: Alluvial fans (outlined in blue) near Lake Point Utah, *Utah Geological Survey*

This Community Guide was a collaborative undertaking by the Utah Silver Jackets Team. Silver Jackets is an interagency partnership effort encouraging federal, state, local, and tribal agencies to work together to find solutions for complex flood risk management issues.

Agencies that contributed to this guide include:

Bear River Association of Governments
City of Saratoga Springs
City of Nibley
Federal Emergency Management Agency
National Oceanic and Atmospheric Administration
National Weather Service
Natural Resources Conservation Service
University of Utah Cooperative Extension
U.S. Army Corps of Engineers
U.S. Forest Service
U.S. Geological Survey
Utah Community Development Office
Utah Division of Emergency Management
Utah Geological Survey

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1 Introduction

Imagine a once-peaceful neighborhood with homes, swing sets, and local businesses that has been turned upside down by a flood. Living rooms have become indoor lakes. Parked cars have been picked up and moved down the street. Large rocks are strewn everywhere.

The devastating flooding described above can take place on a landscape feature known as an alluvial fan. As the name suggests, an alluvial fan is a fan-shaped deposit of sediment, also called alluvium. Alluvial fans are located at the mouths of canyons and develop over thousands of years. Over time, each flood exiting a canyon flows in a different, unpredictable direction.

For millennia, natural processes have driven the creation of a patchwork of alluvial fans across the Utah landscape. Yet these geologic timescales are at odds with human timescales. A picturesque hillside may seem to be the perfect place for a neighborhood until a flood event. Even if your home isn't built next to an obvious stream or channel, it could still be at risk. Alluvial fan flood paths are difficult to predict—floodwaters from mountains exit a canyon and travel onto the valley floor, flowing in a new direction each time. In one rainstorm, floodwaters may go one way, cutting a path through a local playground and baseball fields. In another rainstorm, floodwaters may take a completely different course, tearing a path through houses, garages, and barns.

To help communities that are located on alluvial fans understand their risk, we have put together this guide. This resource will help residents in places of concern plan for and proactively manage fan-related risks. Read on to find out more.

Visualization Box 1: Picturing flood waters with unpredictable directions

Imagine a beach ball and a glass of water. Picture placing the beach ball on the ground and then pouring the glass of water onto it. Can you predict where the floor will get wet? Now, imagine the beach ball is covered in sandpaper. Take that same cup of water. Pour it on the rough surface and try to guess where the water will go. It is impossible to predict where the water will end up under these conditions. This image is a helpful comparison for picturing the type of flooding called alluvial fan flooding. *Images sourced from: https://www.cookooree.com/ (left) and https://starpng.com/ (right)*

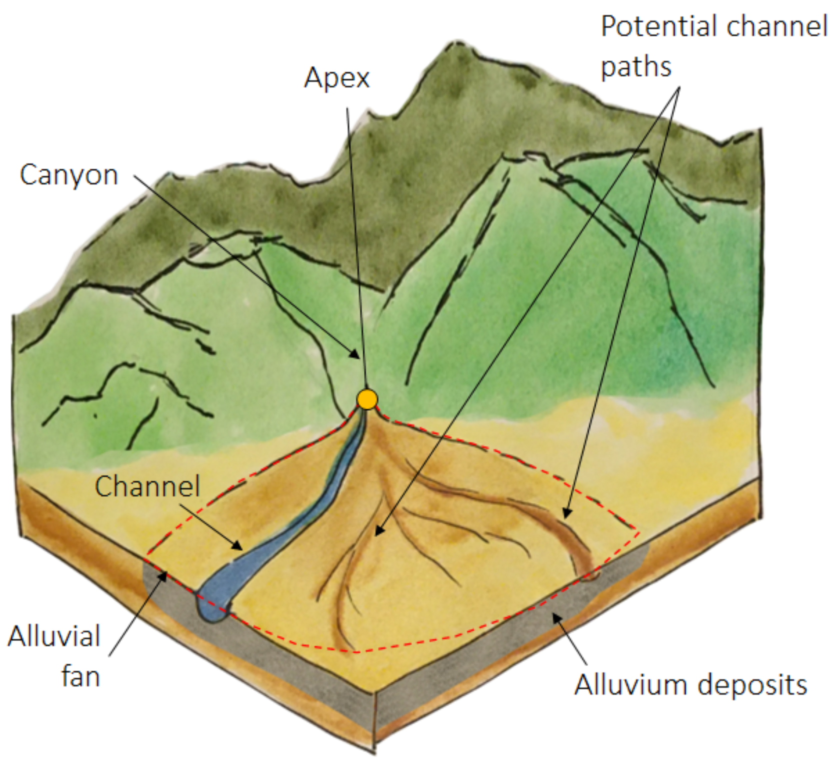
2 Understanding alluvial fan hazards & risks

Flooding that originates from adjacent mountains and hills and empties onto a valley floor, traveling in unpredictable directions, is known as alluvial fan flooding. At the mouths of canyons throughout Utah, communities are faced with the challenge of protecting themselves against alluvial fan flooding.

2.1 What is an alluvial fan?

Alluvial fans are found at the foot of mountains and hills, just below the mouths of canyons.These canyons and their streams are dry much of the year. As the name suggests, an alluvial fan is a fan-shaped landform consisting of sediment loosely deposited by stormwater. Alluvial fans form over tens of thousands of years as floods carry sediment, or "alluvium", from the mountains and hills and deposit those sediments when floodwaters reach flatter areas. Over time, this process builds a gently sloping feature that can be hundreds to thousands of feet across.

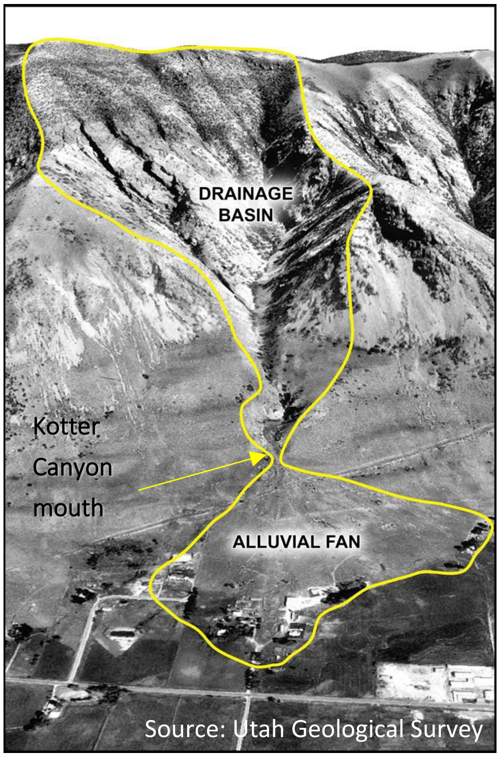
Concept Box 2.1: Learning to recognize the features of an alluvial fan



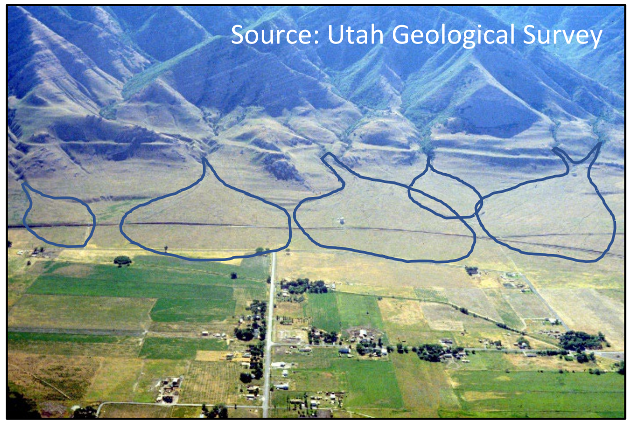
An alluvial fan (outlined by the dashed line) is a fan-shaped deposit of sediment, also known as "alluvium" (shown in gray as part of the below-ground view). The narrow portion of the fan is known as the "apex." The apex is found near the canyon mouth and is the highest point of the alluvial fan. After a storm, water rushing down the canyon exits into the valley and cuts a channel through the alluvium. Each time there is a flood, the water flows in a different, unpredictable direction. These potential channel paths are strewn across the fan.

Visualization Box 2.1: Snapshots of alluvial fans

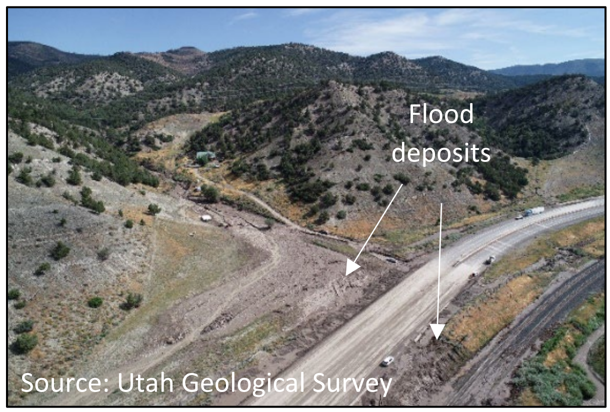
If you live in Utah, you have almost certainly encountered an alluvial fan. These photos of alluvial fans can really help to visualize what these landforms look like.



Above: Drainage basin and alluvial fan downstream of the mouth of Kotter Canyon located north of Brigham City, Utah.



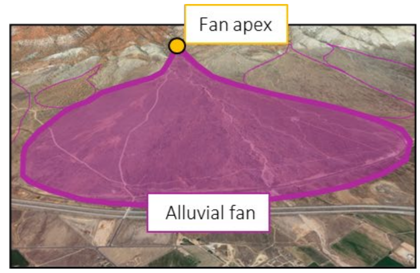
Above: View of alluvial fan deposits near Lake Point, Utah.

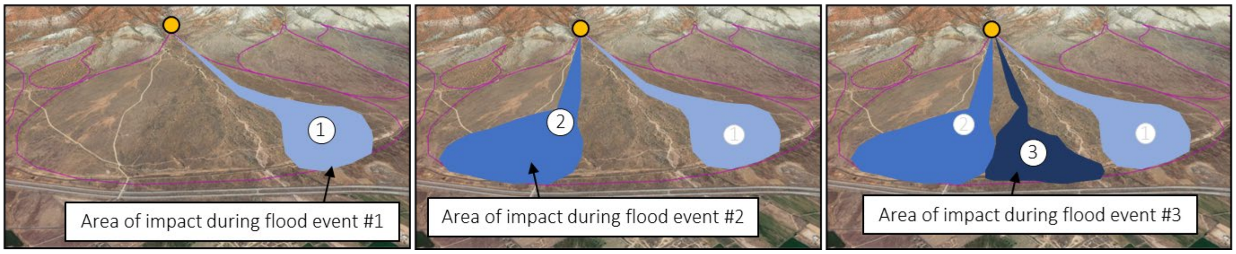


Above: Drone photo taken after an alluvial-fan flood event in August 2019. Image shows flood clean-up and remaining deposits from Garner Canyon along highway US Route 6 in Spanish Fork Canyon.

Visualization Box 2.2:
Picturing the creation of fan-shaped landforms

The unpredictable direction of floodwaters is a primary reason for the fan shape that gives “alluvial fans” their name. This photo sequence shows outlines of alluvium deposits of three flood events on the same alluvial fan. A progression of flood deposits builds the fan. *Images sourced from Google Earth*





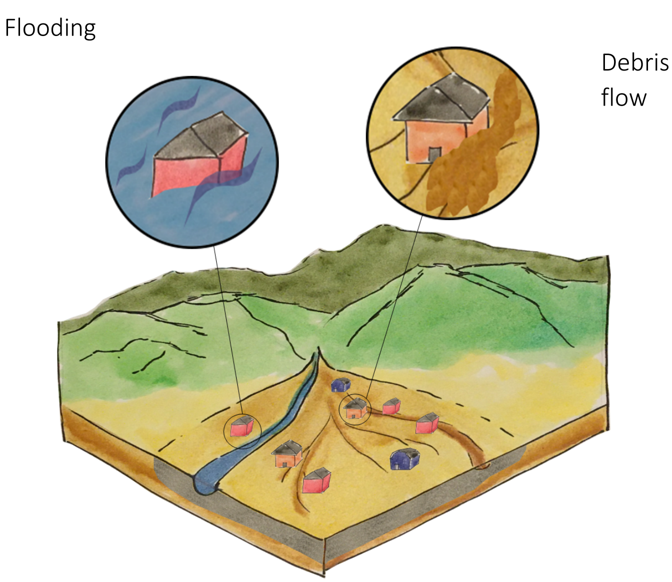
2.2 Alluvial fan hazards

A hazard is a condition that can pose a threat or cause harm. Anyone who lives or works on an alluvial fan should be aware of two hazards: (1) flooding and (2) debris flows. Both hazards can be even more destructive if they occur after a wildfire upstream in the watershed, as discussed in section 3.2 of this guide.

Concept Box 2.2a: Learning to describe alluvial fan hazards

Flooding

- Direction of floodwaters is different during each flood event (does NOT follow pre-defined channel)
- Depth of flood water different each time
- Fast moving floodwaters



Debris flow

- Contains water AND debris that ranges in size from small sediments up to big boulders
- Depth of debris varies (up to 8 ft)
- Debris flows move as fast as 35 mph
- Debris loads have higher impact on structures than water alone

Floodwaters that travel across an alluvial fan cut unpredictable flow paths during each flood event. Alluvial fans typically consist of loosely deposited sediments that are easily eroded and moved by floodwaters, so the location and size of channels is constantly shifting and, as a result, predicting the shifts is almost impossible. Furthermore, alluvial fan flooding can occur with little or no warning—flash floods exiting canyons can cause damage miles away from where a rainstorm occurred.

Concept Box 2.2b: Learn to differentiate between flood hazards and debris flow hazards

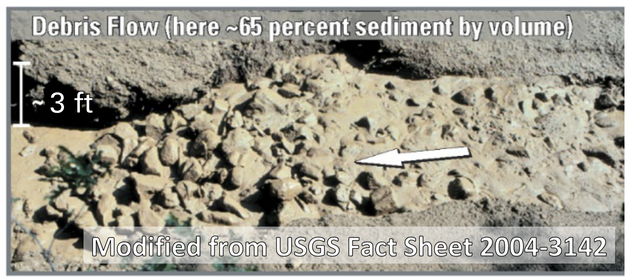
Both flooding and debris flow hazards exist on most Utah alluvial fans.

What is a "flood"?

- Water that overflows a channel or banks
- Generally less than 5-10% sediment by volume
- Direction of flow is controlled by the water

Left: Image of flood flow

Below: Image of debris flow



What is a "debris flow"?

- Sediment and water mixture (think concrete) that can include cobbles and large boulders
- Generally at least 60% sediment by volume
- Direction of flow is controlled by the sediment

Debris flows occur less frequently than floods but are generally much more damaging. Because the impacts of debris flows on alluvial fans can be significantly greater than the impacts of a flood, additional risk reduction measures may be warranted to address debris flow hazards. While this Community Guide primarily focuses on alluvial fan flood risk management, some strategies presented in this guide may be useful for initiating a community-wide discussion on hazards related to debris flows.

To learn more about debris flows, you can access the following resource online:

- Utah Geological Survey guidelines for geologic investigation of debris flow hazards on alluvial fans in Utah (see page 75): https://ugspub.nr.utah.gov/publications/circular/c-128.pdf

Debris flows refer to fast-moving mixtures of sediment and water that generally occur after an intense rainstorm or following periods of snowmelt. Debris flows usually originate on steep hillsides and pick up speed as they travel downhill. Typical speeds for a debris flow clock in around 10 miles per hour, but sometimes can exceed 35 mph. For comparison, a human can move at 6 mph while jogging.

Debris flows travel much faster than floodwaters and exert forces strong enough to significantly damage or destroy buildings and vehicles. Debris flows can grow in volume with the addition of water, sand, mud, boulders, trees, and other materials as they flow down hills and through channels. When a debris flow reaches flatter ground, the debris spreads over a broad area, adding new sediment to the alluvial fan.

Note that this guide is aimed primarily at reducing flood risk, yet some strategies presented may also be effective in managing debris flow risks as well.

2.3 Alluvial fan flood risk

Risk is the likelihood of an event, such as a flood, resulting in negative consequences, such as damage to property. Consider this example: imagine two people are crossing an ocean. One is traveling on a cruise ship. The other is in a rowboat. Both individuals will be subject to the same hazards: the ocean's depth and its large waves. However, the likelihood that each individual will fall off his or her vessel and experience the consequence of drowning is different. Ultimately, the person in the rowboat has a much riskier voyage ahead. This example is illustrated further in Visualization Box 2.3.

Visualization Box 2.3: Picturing the relationship between hazard and risk

Imagine you are crossing the ocean. It will be a long journey with deep water and plenty of waves. Both the depth of the water and the constant waves represent ocean hazards.

Now, you have two choices for your ocean journey. You can travel in a rowboat, or you can travel aboard a cruise ship. If you choose the cruise ship, what is the likelihood that the deep water and waves will cause harm to passengers? The chance is quite low. But how about the rowboat? What is the chance that the water depth and constant waves will cause harm to a rowboat passenger? The chance is much greater.

In both examples above, the hazard remains the same. The ocean will always be deep and there will always be waves. However, the risk involved in crossing an ocean in a rowboat is much higher than the risk involved in crossing an ocean in a cruise ship. Transfer this concept to an alluvial fan. If two alluvial fan landforms have a similar hazards, but one has no development and the other has been developed with houses and businesses, the risk of damage to property will be much greater for the developed fan. *Images sourced from: https://www.kindpng.com/ (top left), https://www.nicepng.com/ (bottom left), and https://www.freepnglogos.com/ (right)*

The same hazard-risk framework can be applied to assess risk for an alluvial fan. Consider a community located in a desert valley, far from the mouth of a canyon. It is not subject to flooding hazards associated with alluvial fans and, as a result, is not at risk of experiencing alluvial fan flooding. Now consider a different community. This one is built on an alluvial fan. Many homes and business are located close to the fan's apex near the canyon mouth. A large portion of this community is subject to alluvial fan flood hazards. As a result, there is a high risk that property damage and life loss will happen when a flood occurs.

A community whose boundaries include an alluvial fan can think about their degree of risk by looking at two key features:

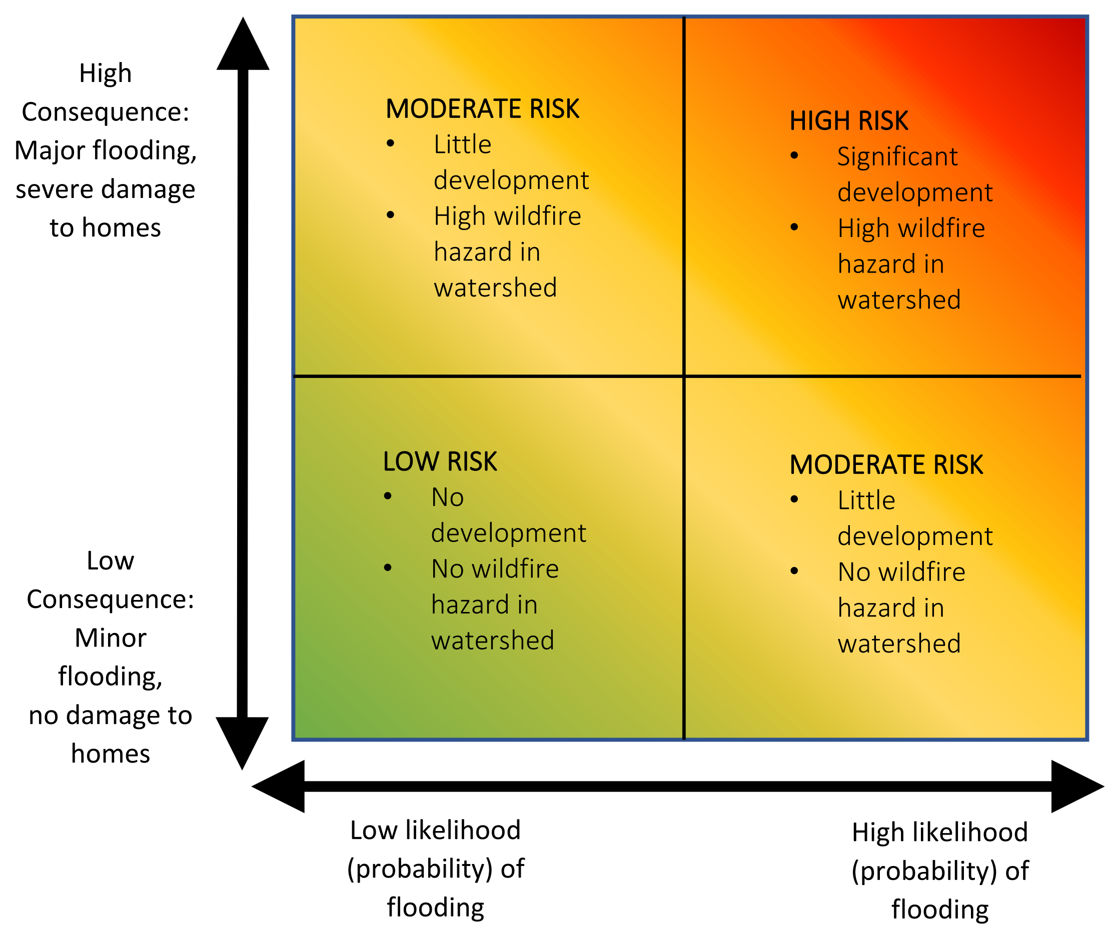
(1) **Development on the alluvial fan:** If existing development has been established on an alluvial fan, those structures and infrastructure are currently at risk.
(2) **Wildfire hazard in the watershed upstream of the alluvial fan:** If there is a wildfire in the watershed upstream of the alluvial fan, burned areas temporarily increase the likelihood of debris flows and flooding due to loss of vegetation and changes in soil conditions.

Concept Box 2.3 presents different risk levels associated with alluvial fans. In which quadrant do you think your community lies with respect to development and wildfire hazard?

Concept Box 2.3: The risk to development on alluvial fans

Areas with active alluvial fans, significant development, and wildfire hazards in the watershed above the alluvial fan are at the highest risk of experiencing negative consequences from alluvial fan flooding.

RISK = LIKELIHOOD X CONSEQUENCE



Floods and debris flows on alluvial fans result from natural processes and are virtually impossible to stop. However, the objective of this guide is to provide a suite of tools that may be employed to reduce the risk of alluvial fan hazards. The following sections of the guide lay out steps to identify, assess, and reduce risks associated with alluvial fans.

Graphic 2.3: Three steps to follow to reduce alluvial fan flood risk

3 Identify hazards

Identify hazards | Assess risk | Manage risk

Much of Utah's development is located near mountain ranges and by the canyon mouths at the foot of these ranges—just where you are likely to find alluvial fans. However, not all communities at the foot of mountains are at risk from flooding and/or debris flow. This section of the guide will present steps to follow to identify whether your community or a planned development is located on an active alluvial fan and subject to its associated hazards.

3.1 Identify the alluvial fan

When mapping an alluvial fan, it will be important to consult existing resources –including professionals—to gain a full understanding of potential hazard(s). Below are several preliminary steps you can take. However, more research will likely be necessary.

- **Consult state and local mapping resources (a geographic professional may be needed)**
    - The Utah Geological Survey (UGS) offers maps that show debris flow hazards. For some areas, there are geologic maps with information on alluvial fan boundaries. Check the UGS webpage to find out more (https://geology.utah.gov/apps/hazards/).
    - Utah Division of Emergency Management (DEM) functions as a Cooperating Technical Partner for the Federal Emergency Management Agency (FEMA). DEM's Risk Mapping, Assessment and Planning (Risk MAP) division coordinates flood mapping for the state. Utah Risk MAP's webpage is: https://floodhazards.utah.gov/. You can also search for your property's flood risk by going to FEMA's Map Service Center: https://msc.fema.gov/portal/home.
        - Note: If you are unable to locate resources for your community in the FEMA Map Service Center, that does not mean there is not a floodplain in your area. Rather, it means a map has yet to be produced. Floodplains exist in areas where FEMA has yet to complete a study. Additionally, FEMA generally does not produce flood hazard maps for watersheds less than one square mile in size. This may also affect the availability of FEMA resources for your community.
    - Local or regional studies may have included efforts to map alluvial fans in a community.
    - Note that, while Utah DEM and UGS offer maps that identify alluvial fan boundaries, site specific flood risk studies may be necessary. These are discussed in the next section.
- **Consult professionals to create/refine a community map**
    - If maps outlining the boundaries of an alluvial fan do not exist for your community, work with a professional such as an engineer, geologist, or hydrologist to create them.
    - The final map of the alluvial fan should show the current boundaries of the fan.
    - Additional investigations that include modeling of predicted sediment depths and velocity of water and debris are recommended and should be done by a geotechnical or hydraulic engineering professional.

3.2 Assess flood potential due to wildfires

The flood and debris flow hazards associated with alluvial fans are linked with conditions in the mountain watershed upstream of the fan. If a watershed experiences a significant wildfire, it is left without sufficient vegetative cover to stabilize the soil. During a rain event, burned areas of the watershed can experience increased runoff. In turn, this can produce a flash flood.

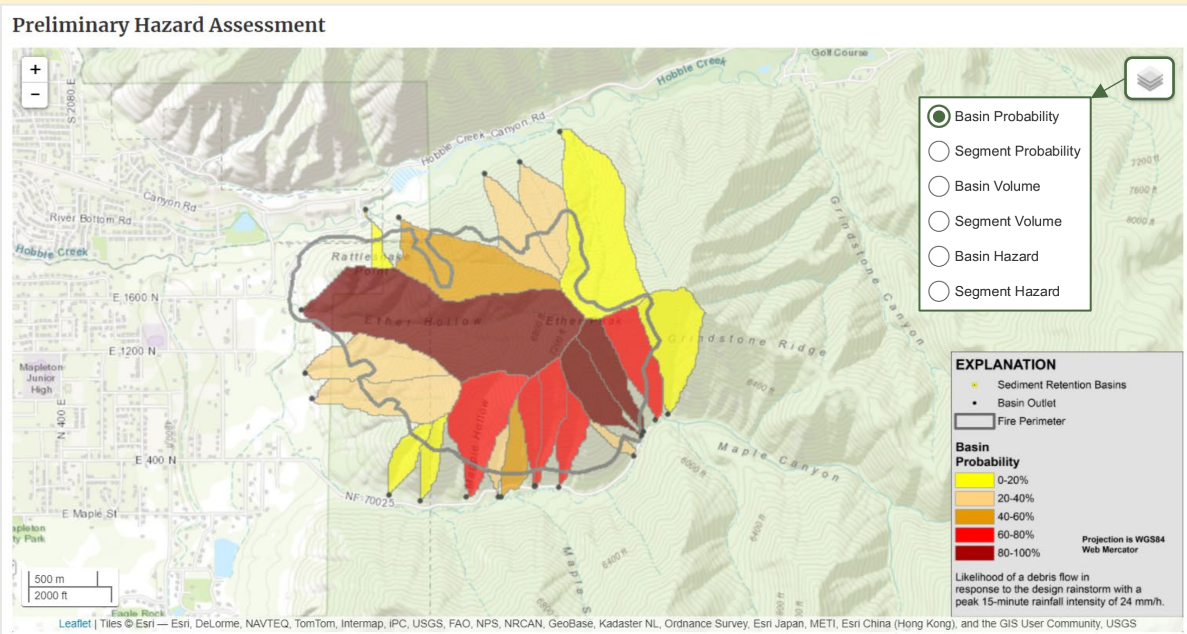
An assessment of wildfire hazard potential is an important step in identifying areas where: (1) local conditions make a significant wildfire event likely and (2) there is development located on or near an alluvial fan. The following sources of information can help you assess the wildfire hazard potential in the upper reaches of your community's watershed. If you find a high potential for wildfire, the pre-fire forest fuels reduction strategy outlined in Section 5.1.6 offers a proactive pathway to reduce the alluvial fan flood risks related to wildfire.

- **Identify your watershed's wildfire hazard potential using the U.S. Forest Service Wildfire Hazard Potential Map**
  The U.S. Forest Service Wildfire Hazard Potential Map can be used by communities to identify the potential for extreme forest fires in the watersheds. The Wildfire Hazard Potential map may be accessed online (https://www.firelab.org/project/wildfire-hazard-potential).
  - On the Wildfire Hazard Potential Map, locate your community and watershed. This is best done in Geographic Information System (GIS) software, combining the Wildfire Hazard Potential map with a map of Utah watersheds
    - GIS files for the Wildfire Hazard Potential Map may be found on the webpage listed above.
    - A GIS layer containing delineated watershed boundaries in the state of Utah can be found at the Utah Geographic Reference Center (UGRC) website (https://gis.utah.gov/data/water/watersheds/).
  - Determine the wildfire hazard potential in the hilly and mountainous areas of the watershed, upstream of the alluvial fan.
- **Consult state and local wildfire hazard resources**
  The State of Utah maintains the Wildfire Risk Assessment Portal which features fire threat maps: (https://utahwildfirerisk.utah.gov/Map/Public/#whats-your-risk). Wildfire threat is linked to the likelihood of an area burning and is mapped as the Fire Threat Index. Attributes used to define the Fire Threat Index include fuel hazards, extreme weather conditions, and topography.
  - On the Wildfire Threat Map, locate your community and watershed. This is best done in GIS software, combining the Wildfire Threat map with a map of Utah watersheds.
    - GIS files for the Wildfire Hazard Threat may be found on the webpage listed above.
    - A GIS layer containing delineated watershed boundaries in the state of Utah can be found at the UGRC web page listed above.
  - Similar to above, determine the wildfire hazard potential in the hilly and mountainous areas of the watershed, upstream of the alluvial fan.

If your community's watershed has experienced a recent fire, Example Box 3.2 contains sources of information to help you assess your post-fire flood and debris flow potential.

Example Box 3.2: Emergency assessment of post-fire debris flow hazards available to communities through online tool

If your community has already experienced a wildfire in an upstream watershed and a federal Burned Area Emergency Response (BAER) Team has assessed the burn scar, the U.S. Geological Survey offers an online mapping tool that displays the likelihood of debris flows in burned watersheds. The tool may be accessed online (https://landslides.usgs.gov/hazards/postfire_debrisflow/). Additionally, the following link will take you to the National Weather Service Post Wildfire Flash Flood and Debris Flow Guide: https://www.wrh.noaa.gov/lox/hydrology/files/DebrisFlowSurvivalGuide.pdf



Above: Screen capture of the U.S. Geological Survey online tool for emergency assessment of post-fire debris-flow hazards. The map above is for the drainage basin affected by the 2020 Esther Hollow Fire. The colors show the probability of debris flow (%) for a hypothetical storm with a peak 15-minute rainfall intensity of 0.94 inches per hour (or 24 millimeters per hour). Measurements for debris-flow volumes as well as other metrics (i.e., basin hazards) can be selected on the map using the menu in the upper right corner.

4 Assess risk

Identify hazards | **Assess risk** | Manage risk

Both a map of an alluvial fan and an assessment of wildfire hazard potential can help a community identify alluvial fan flood and debris flow hazards (i.e., conditions that can cause harm). With knowledge of hazards in hand, a community is ready to determine its risk (i.e., the likelihood these conditions will cause harm). If necessary, refer back to Visualization Box 2.3 and Concept Box 2.3 for a refresher on the difference between risk and hazard.

4.1 Analyze level of risk

After a hazard map has been completed for a community, you will know the boundaries of an alluvial fan. Your assessment of wildfire hazard potential will give you information about wildfire risk upstream of the fan apex. Now what? Knowing where the fans are located is not enough. This section offers guiding questions and actions for relating hazards identified to alluvial fan flood risk in your community. The suggestions below are only a starting point. Further studies such as a flood study or geological study will likely be required to determine the most accurate and current risk before determining how to reduce risk. Similarly, this guide presents risk reduction measures specific to alluvial fans. Flood hazards may extend beyond the boundaries of the fan and should be accommodated during the planning phase to reduce overall flood risk to the community.

- Consult Federal Emergency Management Agency (FEMA) mapping resources
    - If available, acquire a FEMA Flood Insurance Rate Map (FIRM) for your area. These maps may be accessed with an online search on FEMA's webpage (https://msc.fema.gov/portal/home). Additionally, available digital data can be viewed on the FEMA National Flood Hazard Layer webpage (https://msc.fema.gov/nfhl). For detailed instructions, see the Property Owner page on the Utah Risk MAP website (https://floodhazards.utah.gov/property-owners/#understand1).
    - FEMA FIRMs show areas of flood risk and may include the extents of an alluvial fan as "Zone A" or "Zone AO". Older FIRMs may designate these areas as "Zone A" but may or may not include a note stating that the area is an alluvial fan. Furthermore, FIRM "Zone A" designations on an alluvial fan can either mean:
        - A detailed flood risk study was performed but the area mapped exceeds flood depths of more than three (3) feet

        ---OR---

        - The "Zone A" designation is "approximate," and no detailed study has been performed to define the flood risk more accurately.
    - Note: On FIRMs, not all alluvial fans have been identified nor has all potential flood risk been identified. Many fans are either unmapped or the FIRM data is extremely outdated. Additionally, FEMA Flood Insurance Study (FIS) reports may note an area as an alluvial fan in the text without showing it or identifying it on the FIRM.

- Even if a FEMA FIRM exists for your community, these maps often do not include enough detail to identify an alluvial fan (see above) and further detailed analysis/studies are suggested in these areas to accurately identify the flood risk.

- **What is the likelihood of damage to property or infrastructure from alluvial fan flooding?**
  If a geologist, engineer, or hydrologist has completed a hazard map for you community using GIS software, he or she may be able to add information to this map that describes locations of houses, businesses, and public buildings (especially critical facilities like hospitals and fire stations). This can help your community assess your risk level. Keep the following concepts in mind as you complete your risk assessment:

  <u>Low likelihood of damage after flood generally associated with:</u>
  - Little/no development on fan
  - Small population/unpopulated

  <u>High likelihood of damage after flood generally associated with:</u>
  - Significant development
  - Large population

- **What is the likelihood that major property damage will occur?**
  Now consult information that has been gathered on wildfire hazard potential as well as information available about flood depths and velocities. On fans or areas of a fans where there is greater wildfire hazard potential, deeper flows, and faster water, there will likely be major damage to property and, even, lives at risk.

  <u>Minor property damage:</u>
  - Low wildfire hazard potential in watershed
  - Little/no development on fan
  - Property or infrastructure located down-fan away from apex

  <u>Major property damage/life loss:</u>
  - High wildfire hazard potential in watershed
  - Significant development on fan
  - Property or infrastructure close to fan apex/canyon mouth

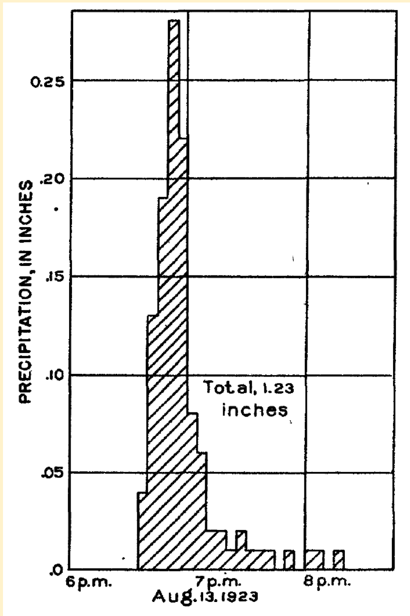
- **Consult professionals.**
  - Remember, knowing a fan's location and the area's general risk level is not enough!
  - Hire a professional to obtain a further study (i.e., a geological or hydraulic study) to determine the most accurate and current risk before making the determinations on how to reduce risk.

4.2 Share and discuss risk assessment results

Communicate risk assessment results to stakeholders. It is important for emergency managers, floodplain managers, city or town officials, tribal leaders, community members, planners, developers, and others to be part of the conversation about risk levels for alluvial fan flooding.

If community risk levels for alluvial fan flooding are high, the aforementioned stakeholders will be important resources during the collaborative planning discussions outlined in Section 5.1.7.

Example Box 4.2: Community attention on flood risk results in risk reduction measures



Above: Graph showing high intensity rainfall data for August 23, 1923 storm . (Source: USGS Water Supply Paper 994)

On August 13, 1923, a storm with intense rainfall within a short period of time caused flooding throughout Northern Utah. In the town of Willard, the alluvial fan at the mouth of Willard Creek canyon experienced a large debris flow. As a result, 155 acres of sediment, or alluvium, covered town lots, gardens, and orchards.

The 1923 storm event and resulting debris flow attracted public attention. Thanks to this heightened awareness of flood risk, plans were developed to reduce the consequences associated with similar flows in the future and, in 1924, a debris basin was constructed. A survey of the basin in 1939 showed approximated 200,000 cubic yards, or 20,000 dump truck loads, of sediment collected by the basin.

Source: Utah State Historical Society

Bottom Left: Photograph of a house in Willard, UT showing alluvium deposits from debris flow caused by 1923 storm.

Bottom Right: an oblique image of present-day Willard, UT. The town is located at the mouth of a deep canyon. The arrow indicates the location of a debris basin.

5 Manage risk

Identify hazards → Assess risk → **Manage risk**

If your community is located on an alluvial fan, develop a community-wide plan to reduce your flood risk and (or) debris flow risk. Furthermore, if an alluvial fan hazard has been identified, avoid new development on the fan. Building new homes or business on an undeveloped fan puts more property and life at risk.

For developed alluvial fans, risk reduction strategies fall into three categories: (1) implementation of community practices/policies, (2) modification of existing buildings and structures for protection, and (3) construction of new protective structures. A successful community-wide plan to reduce alluvial fan flood risk will use multiple strategies, often combining different options. The next section of the guide outlines some measures that may be adopted in each of the three risk reduction categories.

5.1 Manage risk through practices & policies

All effective risk reduction plans include non-structural strategies that rely on community practices and public policies to keep property damage and life loss to a minimum.

Many communities in Utah already have non-structural risk reduction programs in place. This section of the guide outlines different ways in which policies or programs dealing specifically with alluvial fan flooding and debris flows can be combined with other efforts. If the practices and policies presented are not present in your community, consider directing resources and time into developing and adopting them.

5.1.1 Expand or develop an Emergency Action Plan

An Emergency Action Plan can include procedures to follow in the event of alluvial fan flooding or a debris flow. If a community has an existing Emergency Action Plan, it can easily be modified to include guidance specific to alluvial fans. It is also possible to add an Emergency Action Plan developed for alluvial fan flooding or debris flows to an existing Emergency Operations Plan as an annex. Similarly, a community may consider adding specific mitigation measures targeting alluvial fan flooding to the Local Hazard Mitigation Plan.

Concept Box 5.1.1: Develop an Emergency Action Plan for active alluvial fans at risk for flooding and debris flows

An Emergency Action Plan provides answers to the “who?”, “what?”, “when?”, and “where?” questions in the case of a natural disaster. Emergency Action Plans, or EAPs, can include:

- When to initiate alluvial fan flood monitoring based on weather forecasts
- Description of the role, responsibilities, and lines of communication between various disaster response entities
- Evacuation procedures, including evacuation areas, evacuation routes, and evacuation time windows

When developing an Emergency Action Plan that is alluvial fan-specific, it is important to note that different areas on a fan may have different risk levels. If buildings or homes are situated close to the top, or apex, of a fan, those residents may need to receive different instructions than the instructions given to residents who reside on the downstream edge of a fan. It will also be key to identify critical infrastructure and vulnerable populations. In the case of the former, consider the location of the communication equipment hub. Is it situated within an area at risk of flooding? When thinking about the latter, consider where facilities such as senior centers are located. If vulnerable properties are near a fan's apex, this will need to be considered.

5.1.2 Consult or establish advanced warning systems

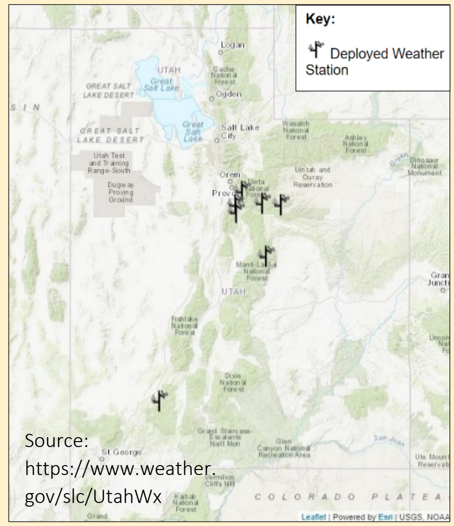
Communities can pursue monitoring assistance at the federal, state, and local levels. Monitoring can occur on and off-site. Remote monitoring stations are commonly used to provide observations on real-time environmental conditions that may produce a significant precipitation event. Remote monitoring stations are especially valuable for communities downhill from an extreme fire event. Several examples are presented on the following page in Example Box 5.1.2.

Example Box 5.1.2: Advanced warning systems are key to successful non-structural risk reduction

Communities have multiple options available to support the monitoring of environmental conditions. Currently sensor networks that measure conditions such as temperature, precipitation, and humidity are deployed in certain parts of the state. Below, more information is included on different sensor networks.

Utah Department of Public Safety automated weather stations (burn scars only)

- Campbell Scientific instruments measure precipitation, temperature, relative humidity, wind speed and direction, among other weather parameters
- Geostationary Operational and Environmental Satellites (GOES) communications
- National Weather Service Weather Forecast Office Salt Lake City, UT (NWS WFO SLC) will assist in site selection and install weather stations
- Information shareable with community leaders and NWS WFO SLC via alert notification, and broader community via MesoWest



Above: Utah Department of Public Safety weather station deployments; the map changes as updates occur online. Visit https://www.weather.gov/slc/UtahWx to find the most up-to-date station information.

Above: UDOT portable RWIS network. Visit https://blog.udot.utah.gov/ to find out more about sensor installation.

Utah Department of Transportation (UDOT) portable Road Weather Information System (RWIS)

- Precipitation, temperature, relative humidity, wind speed and direction, among other sensors
- UDOT determines site selection, sometimes in collaboration with WFO SLC, and installs sensors
- Information shareable with community leaders and NWS WFO SLC via alert notification, and broader community via MesoWest

America's Weather Industry automated weather stations

- Precipitation, temperature, relative humidity, wind speed and direction, among other sensors
- Community determines site selection, sometimes in collaboration with WFO SLC, and installs sensors
- Information shareable with community leaders and NWS WFO SLC via alert notification, and broader community via MesoWest
- More information can be accessed online at https://www.weather.gov/about/weather-enterprise

5.1.3 Engage in risk communication

Community residents with homes on alluvial fans may not understand their risk from unpredictable and potentially violent flooding or debris flow events. It is key to provide accurate information and guidance that will help community members make informed decisions to better protect themselves. Public outreach events and public information campaigns can be key opportunities to connect with community members. Place information on websites and social media or locations where you reach residents the most.

Concept Box 5.1.3a: Did you hear?! Ideas for risk communication

Many of the ways in which your community is already connected can provide an excellent opportunity to get the word out about alluvial fan flood risk. Do you have a Facebook page already set up? Use it to make a post. Are regular mailings already sent out to residents? Incorporate messaging about risk into these flyers. A few ideas are listed below.

- Websites
- Social media
- Reverse 911
- Information in water (or other local) bills
- Direct mailing
- Door-to-door (door hangers)
- Community public events (tables at fairs or events where a large audience is reached)
- Community event addressing the specific issue

Concept Box 5.1.3b: Important guidance to highlight for residents living on active alluvial fans

Risk communication is an important non-structural risk reduction measure. When providing guidance to residents who may live on an active alluvial fan, consider adding the following guidance to any information you are already providing about warning systems and evacuation protocols:

- **Beware of basements:** Many houses in Utah include basements. If a house on an active alluvial fan has a basement, this level of the house is *below* the flood or debris flow level that would result from an alluvial fan flood event. If possible, avoid sleeping in the basement, especially during times of the year when flooding or debris flow are particularly likely. Similarly, avoid storing valuable equipment or important records in a basement. During an event, they may suffer water damage or become buried in debris. In general, risk levels associated with alluvial fan flooding, debris flows, and even riverine flooding should inform development of new homes with basements if the homes are to be built in high-risk areas.
- **Prepare a "Go Bag":** Because alluvial fan flooding and debris flows are often triggered by short, intense storms (i.e., a thunderstorm or "cloudburst" storm), residents need to be ready to evacuate their home at short notice. Having a "Go Bag" that includes shelf-stable food, water, flashlights, warm clothes, and other essential items will allow residents to get to a safe location as quickly as possible. Ideas for what to include in a "Go Bag" can be found at www.ready.gov/kit and https://www.utah.gov/beready/family/get-a-kit.html
- **Avoid attics:** Flood and debris flows on alluvial fans triggered by storm events can sometimes leave residents without enough time to evacuate. In this case, the roof of a house is the safest place to be. While an attic may provide temporary shelter from precipitation, it can also cause residents to become trapped if flood depths reach above a certain height.

5.1.4 Educate community members about flood insurance

Typical homeowner's or renter's insurance policies do not cover flood or debris flow damages. It is important to educate residents living on an active alluvial fan about flood insurance. They should be made aware of the National Flood Insurance Program (NFIP), which is a federally backed insurance program managed by FEMA. Insurance may be purchase through the NFIP to cover the cost of damage to a structure and its contents. Flood insurance is also available for non-residential locations. More information about the NFIP as well as instructions for finding a local insurance agent may be found online (https://www.fema.gov/flood-insurance and https://www.floodsmart.gov/)

It is important to note that while flood insurance may protect against economic damages, it does not reduce personal safety risk. Additionally, there are generally no options for debris flow insurance.

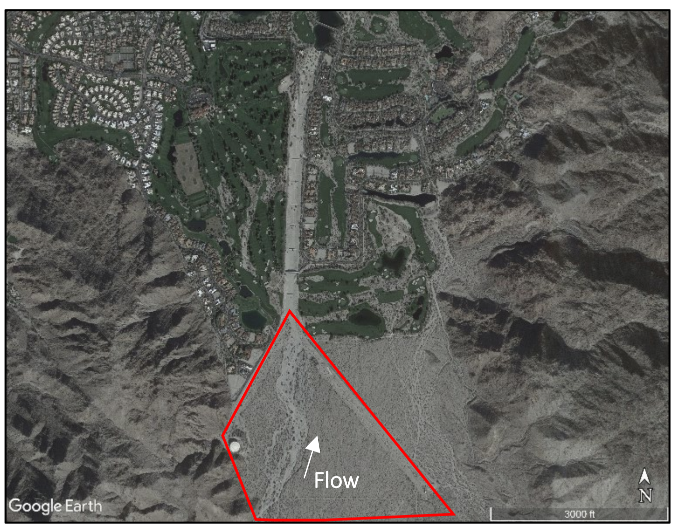
5.1.5 Develop strategic practices for future land use planning

Current building codes do not permit construction of new commercial or residential structures on alluvial fans. In areas where new structures are permitted, a little creativity can go a long way. With some strategic planning, alluvial fan areas can be designated as parks, outdoor amphitheaters, and other non-permanent structures.

Concept Box 5.1.5a: Planning for open spaces and passive uses on active alluvial fans

Land on an alluvial fan provides a unique opportunity to celebrate community. Planning to establish an open space such as a park or another passive use such as an outdoor amphitheater on an active alluvial fan will help prevent economic damage and life loss in the future. Plans are developed on a case by case basis at the community level. Some past examples include:

- Athletic park
- Dog park
- Formal gardens
- Plaza or community commons
- Campground
- Archery range
- Performing arts venue
- Wildlife sanctuary
- Motocross area
- Skateboard park
- Golf course
- Environmental mitigation



Above: Aerial view of Indian Wells, California. This community was planned to have streets align with expected alluvial fan flood flow paths. Note that the linear N-S feature is a channel constructed to convey storm runoff away from a residential development. Flow direction is towards the top of the image and parallels the main road. Additionally, the highest risk areas on the fan were designated as a golf course. For reference, the alluvial fan is outlined in red.

Concept Box 5.1.5b: Overview of building codes on alluvial fans

Developing and permitting in Utah is governed by building codes. There are two building codes to be aware of: (1) the International Residential Code (IRC) and (2) the International Building Code (IBC). The IRC and IBC are the bases for most residential building codes adopted in the United States and in Utah, but each community's building codes may vary from these model codes. It is important to consult with local building officials to confirm which requirements apply to a given community.

NFIP requirements for buildings and structures are subject to the latest editions of the IRC and IBC, as directed by FEMA. While the IRC includes requirements for new construction or improvements on a floodplain, it doesn't provide specific provisions for alluvial fans. Instead, the IRC defers to the American Society of Civil Engineers (ASCE) 24 standard for areas with high flood risks, such as alluvial fans. Below are several key pieces of information to keep in mind in relation to ASCE 24 and NFIP.

ASCE24
AMERICAN SOCIETY OF CIVIL ENGINEERS

- ASCE 24 prohibits new development or substantial improvements in alluvial fan areas unless a whole-fan risk reduction system is in place (see section 5.3.2 for examples of whole-fan risk management)
- Even if ASCE 24 is not required, a developer should still consider hazards posed by an alluvial fan and execute these best practices:
  - Building foundations should be deeply embedded to resist scour, high velocity flood and mudflow, and debris impact
  - The site should be graded to allow water to flow away from buildings

NATIONAL FLOOD INSURANCE PROGRAM

- NFIP requirements for structures on alluvial fans (which are identified as "Zone AO" on FIRMs) include the following:
  - Adequately anchored structures
  - Lowest floor of a structure (including the basement) must be above the highest adjacent grade
  - Materials used to build the structure at elevations below the lowest floor must be flood resistant
  - Structures must have adequate protection from high velocities and debris loads

In addition to intentional design and community planning, it is important to consider acquisition of structures on high-risk fans. If a flood or debris flow occurs and damages a structure beyond the reasonable cost of repair, it may be possible to compensate the property owner and acquire the high-risk land. This provides an opportunity to repurpose the area into an open or passive-use space.

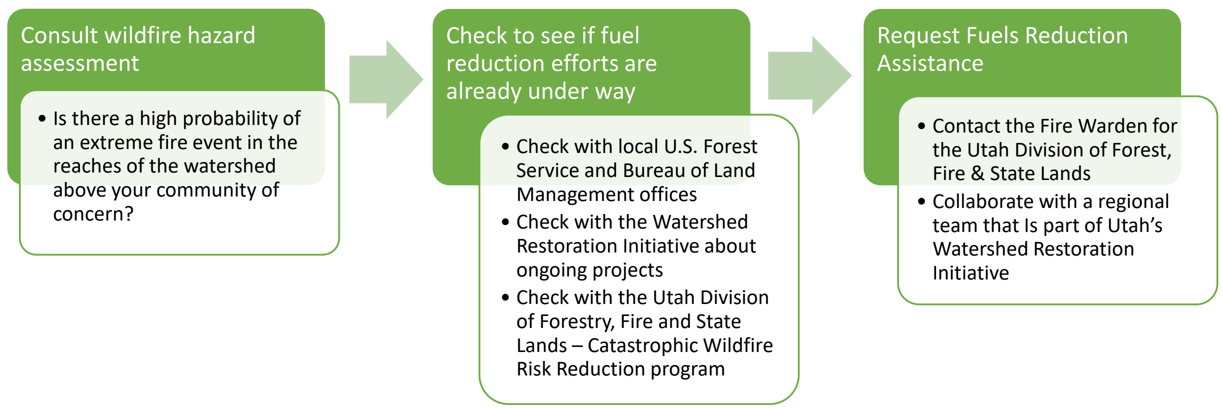
For the long term, consider land use regulation and introduction of zoning requirements specific to high-risk areas on alluvial fans. Regulations to require newly built structures to be elevated would minimize the amount of retrofitting required.

5.1.6 Practice active watershed management

Alluvial fan flooding and debris flow risk is tied to conditions of the watershed. When a wildfire occurs in a watershed upstream of a fan, the likelihood of rainfall moving sediment and debris into stream channels and onto the fan greatly increases.

Forest fires are a natural part of ecosystem processes in the mountains of the West. However, wildfire suppression over the past century has allowed some forests to grow so dense that the likelihood of more severe and larger wildfires has increased. Climate change is also likely to worsen wildfires.

Chart 5.1.6: Three steps to follow to reduce wildfire risk in the watershed upstream of an alluvial fan



Forest "treatments" in the watershed can reduce "fuels," or dense vegetation, decreasing the likelihood of severe wildfires and subsequent flooding and debris flows. Fuel treatments reduce forest density by cutting or thinning the understory as well as through the use of prescribed burns. By thinning high wildfire risk areas of a forest, it is possible to reduce the likelihood of a severe or large wildfire.

If, while using the wildfire hazard potential and wildfire threat mapping tools described in Section 3.2, you have concluded your watershed likely warrants a reduction in fuels, the steps below provide a guide to taking advantage of existing State of Utah and federal natural resource management programs that address fuels reduction strategies. Be aware that programs are constantly being modified, so the programs mentioned at the time of this publication may be different than those available in the future.

- **Determine: Are fuel reduction efforts to reduce wildfire risk already underway?**

  The U.S. Forest Service and the Bureau of Land Management manage most of the federal lands in Utah. To determine if these agencies would consider planning fuels mitigation activities that would minimize the risk level of alluvial fan flooding or to determine if these activities are already underway, contact the offices overseeing the natural resource management of federal lands in your watershed. For the Forest Service, contact the local District office. For the Bureau of Land Management, contact the local Field office. The State of Utah Division of Forestry, Fire and State Lands is also taking proactive steps to manage forest fuels. Additional information about fuels reduction efforts and opportunities underway at the state level may be accessed online (https://ffsl.utah.gov/fire/).

- **Work with existing programs to get assistance with wildfire fuel reduction**

  If you have determined your locality would like to request fuels reduction assistance for areas in the upper reaches of your watershed, the following actions presented in this section are recommended. Note that entities from private landowners to cities and counties can request assistance. By joining a team comprised of multiple stakeholders, you may be able to increase the likelihood of receiving assistance.

  Fuels reduction projects not only minimize the risk of exacerbated alluvial fan flooding effects but can also improve wildlife habitat and ensure clean drinking water supplies. Strong fuel reduction project proposals typically provide multiple benefits to both communities and wildlife, and plans with more benefits are more likely to be supported and funded. Opportunities to engage with programs that provide fuels reduction assistance and that exist at the time of this publication are described below.

  - Contact the county Fire Warden with the Utah Division of Forestry, Fire and State Lands. The Division will then serve as a liaison to the U.S. Forest Service and the Shared Stewardship program, which combines funding from state and federal funding vehicles to address priority forest treatments.
  - Collaborate with a regional team involved with the Watershed Restoration Initiative through the Utah Department of Natural Resources. In addition to seeing to improve watershed health, the Watershed Restoration Initiative also seeks to reduce fuels in high-fire hazard potential areas. By participating in the program, communities work with Habitat Managers and Restoration Biologists with the Division of Wildlife Resources to develop strong plans for fuels reduction projects. Habitat Managers can help seek project funding from multiple funding sources, beyond funds from the Shared Stewardship program. More information about the program and its regional locations may be found online (https://watershed.utah.gov/).
  - Work with a local government agency to determine your community's eligibility for funds through the Wildland Urban Interface Grant Program (https://www.westernforesters.org/wui-grants).

5.1.7 Collaborate with community stakeholders

Reduction of risk on an alluvial fan can be accomplished through the development of a fan-wide community strategy and community plan that incorporates all watershed stakeholders. Watershed stakeholders are a diverse group and include both people who make and implement decisions as well as those who are affected by decision outcomes. Watershed residents, property and business owners, public works department employees, tribal members, local representatives, and state agencies are all examples of stakeholder groups. A collaborative approach to decision making around alluvial fan flood risk ensures that all relevant stakeholders are aware of alluvial fan hazards and risks and are involved in the process of developing a strategy to reduce those risks. The outcome of this collaborative process may include both structural measures and non-structural measures to reduce alluvial fan flooding risks.

A collaborative approach on a watershed-wide scale is warranted as actions taken may have impacts on other watershed stakeholders. For example, measures implemented upstream may have unintended impacts on activities or projects by other stakeholders downstream. If a collaborative watershed effort, such as the Utah Watershed Restoration Initiative, is already ongoing in your watershed, participation in that process could prove to be fruitful in developing a holistic natural resource focused strategy.

If a collaborative watershed management effort is not already established in your watershed, another approach is to initiate a collaborative effort aimed towards developing an alluvial fan flooding risk reduction strategy. Elements involved in forming a collaborative process are highlighted in Concept Box 5.1.7 below. Ideally, the collaborative process should be led by a facilitator who has experience working with stakeholders, has experience in natural resources, and who is trusted by all stakeholders. Facilitators

Concept Box 5.1.7: Collaboration in your community: steps to work together to reduce alluvial fan flood risk

First, develop a stakeholder involvement plan:

1. Identify the area where alluvial fan flooding hazards impact residents, businesses, or infrastructure
2. Identify the stakeholders: residents, local governments, tribal members, private sector, etc.
3. Develop a strategy for involving stakeholders in the collaborative process
    a. Initiate contact to invite them to the process: knock on doors, send letters, and make phone calls, attend other meetings stakeholders attend to get the word out
    b. Interview each stakeholder to identify their values, interests, and concerns: consider written surveys, verbal conversations, etc.
    c. Gather interested stakeholders at an initial meeting to identify and share:
        i. mutual values, interests, and concerns
        ii. purpose of stakeholder participation
        iii. information on alluvial fan flooding and associated hazards.
    d. Hold a second meeting to establish a schedule for the process and identify problems, opportunities, objectives, and constraints of the strategy

Second, assess your situation:

1. Assess alluvial fan related hazards for your community. (See Section 3.1)
2. Assess the hazard potential for wildfires to occur in the upper reaches of your watershed and above the alluvial fan. (See Section 3.2)
3. Using hazards identified above, assess: what is the alluvial fan flood risk for your community? (See section 4.1)
4. Readiness assessment: How ready is your community to withstand alluvial fan risks?
5. Risk reduction assessment: Which risk reduction measures in Section 5 are appropriate for your situation; eliminate those that are not.

Next, develop a strategy or plan to implement risk reduction measures.

1. Establish goals for achieving risk reduction; the goals agreed upon by the group will provide the framework for tracking progress, guiding prioritization, and marking successful risk reduction
2. If risk is high, prioritize urgent and easy to implement strategies. Implementing more complicated measures will require more planning

→ Keep in mind during the collaborative process: ←

1. Focus on a watershed scale
2. Ensure the process is inclusive
3. Practice consensus-based decision making
4. Strive for stakeholder commitment to the long-term collaborative effort

with this experience can be found through organizations such as the Quivira Coalition and Holistic Management International.

From the outset, any collaborative process should include a diverse group of stakeholders. Representation across genders, race, and religious beliefs will strengthen the conservation work and increase community buy-in. When setting up meetings or sending out communication, take into consideration times that work for most people.

The goal of a collaborative approach to alluvial fan flood risk reduction is to provide an opportunity to work through differences and articulate shared values. Disputes may take time, patience, and careful relationship building to ensure trust and cooperation among stakeholders. Decisions should be made by consensus and, since achieving consensus can take time, facilitators and stakeholders should focus on a commitment to collaboration and a shared vision. Additionally, a collaborative approach to alluvial fan flood risk reduction should take time to establish clear guidelines around participation, decision making, and dispute resolution to help keep the collaborative effort intact during more challenging discussions. To encourage and maintain momentum, the collaborative effort may also incorporate workshops that create space for stakeholders to share and expand their knowledge of natural resource issues and science pertaining to alluvial fan flooding hazards. The collaborative process is a long-term, iterative planning and management process that relies on clear and routine communication coupled with monitoring and evaluation to improve decision making and action.

5.2 Manage risk by modifying existing buildings and structures for protection

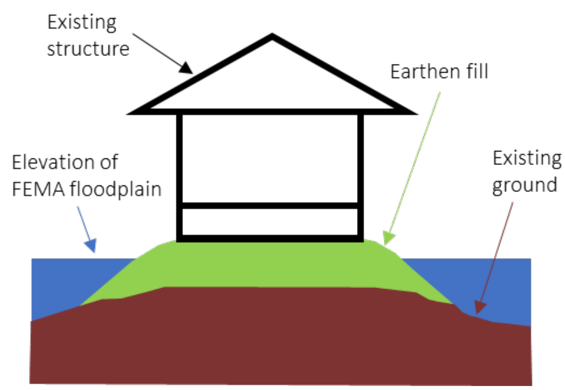
Buildings and homes that already exist on a high-risk alluvial fan may be modified to reduce the risk of economic damage and life loss in case of a flooding or debris flow event. This guide presents two different modification approaches. One approach presented (e.g., the elevation of structures) is a long-term solution. The other approach (e.g., flood proofing) falls into the short-term category and should only be used in case of emergency.

It is important to note that modification of a single structure can inadvertently transfer flood risk to neighbors. Any modifications that do so should be part of the coordinated community-wide plan to reduce alluvial fan flood risk. Coordinating property owner actions that may result in inadvertently directing debris flows to adjacent properties is particularly important. Modifications to existing structures are subject to local building codes (see section 5.1.5) and, if allowed, may require permits from a local agency. Before implementing any of the risk reduction measures outlined in this guide, check with local officials (i.e., floodplain administrator, building official).

5.2.1 Elevation of existing structures

Risk reduction for alluvial fan flooding and debris flow is sometimes accomplished by raising the elevations of individual structures to above flood level (i.e., Base Flood Elevation). In addition, when elevating structures, it is important to account for other risks such as earthquakes. In the State of Utah, it is most appropriate to elevate a structure on an embankment of sediment fill or with an extended foundation. Review your local Flood Damage Prevention ordinance in your community's code as well as the IBC/IRC codes for development requirements (see Section 5.1.5). Further guidance from FEMA is also available.

Concept Box 5.2.1: Elevating existing structures on earthen fill



5.2.2 Flood proofing of existing structures

There are two types of flood proofing: (1) dry flood proofing and (2) wet flood proofing. Dry flood proofing involves sealing a building with waterproof compounds to prevent floodwaters from entering and causing damage. Wet flood proofing, on the other hand, does not seal a building from floodwaters. Instead, vulnerable items in the structure (i.e., appliances, furnace, etc.) are relocated to high locations. During a flood, when water enters a structure that has undergone wet flood proofing, the forces exerted by water on the inside of the inundated building can equalize with the forces water exerts on the outside of the building, reducing the risk of damage to the structure.

Flood proofing existing structures is only appropriate for building and homes located far from the fan apex/canyon mouth. Dry and wet floodproofing are most effective in areas where flood depths are shallow and velocities are low.

Dry flood proofing risk reduction measures many include:

- Reinforcing the up-fan side of structure (i.e., wall that faces the canyon) as windows, doors, and utility connections are particularly vulnerable to failure during an event
- Permanently blocking windows and doors on an up-fan wall of a structure will provide reinforcement in case of a flood or debris flow

Wet flood proofing risk reduction measures many include:

- Relocation of furnace, water heater, appliances, electronics, and other valuable items to a higher location (see Concept Box 5.1.3b for discussion of basements)

5.3 Manage risk by building new protection structures

If all other measures have been exhausted or taken into consideration, new protection structures can be built on an active fan as part of the larger plan to reduce flood risk. Risk reduction structures for alluvial fans aim to trap or direct water and sediment during a flood event. Here the focus is on long-term risk reduction and present protection structures intended to be permanent.

Permanent protection structures built to reduce alluvial fan flood risk are:

- In place long before a flood
- Effective during a flood
- Remain intact after a flood
- Regularly inspected and maintained, including following all flood events

Protection structures are appropriate for fans that have already experienced development. If an active alluvial fan has been identified and is not developed, avoid building new homes or businesses on the fan. This section of the guide presents permanent protection structural measures that may be built on developed fans to reduce the risk of flooding and debris flow events.

Example Box 5.3: Damage caused by debris flow on fan in Santaquin neighborhood

In September 2002, a debris flow cut through a housing development in Santaquin, Utah. The neighborhood was constructed on an alluvial fan. The 2002 debris flow was caused by a short duration, high intensity thunderstorm on Dry Mountain. Previously, during the summer of 2001, an 8,000 acre wildfire on Dry Mountain left slopes relatively bare in the portion of the drainage basin immediately upstream of the alluvial fan apex.

Above: Image of path of debris flow through Santaquin neighborhood.

Above: Wall breached by force of debris flow

Structural damage from debris flow on alluvial fan included:

- Breached outer house walls
- Filling/flooding of basements with debris
- Buckled garage doors
- Buried vehicles

The debris flow also tore a natural gas meter from its mount, leading to a small fire and gas leak. The cost of damages, which included major damage to five houses and two businesses as well as minor damage to 27 houses, totaled approximately $500,000.

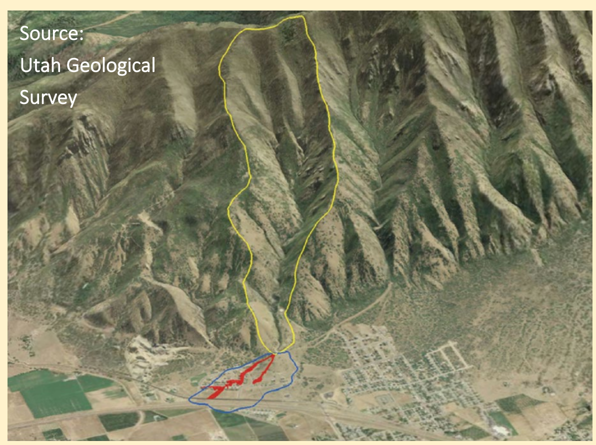


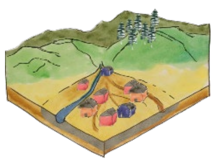
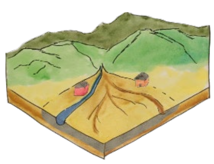
Image credit: Utah Geological Survey Public Information Series 90

Right: The Dry Mountain drainage area (outlined in yellow) is upstream of an alluvial fan (outlined in blue) and was subject to debris flows in 2002 (outlined in red).

5.3.1 Determine scale of new protective structure

Before choosing a protective structure—or combination of protective structures to build on a fan—it is important to determine an appropriate scale for the project. Design and construction of new permanent protective structures is a multi-year process, and great care should be taken when determining the best approach. Consult with a design professional to help make these determinations.

Table 5.3.1: Determining project scale for risk reduction measures

Project Scale	Intent of structure	Examples	Potential Benefits	Potential Challenges
Whole fan protection 	Appropriate for extensively developed fans; aims to intercept flows and debris at or above fan and transport them around the fan	• Debris basins • Levees • Enhanced alteration to channels	→ Large scale structures are appropriate for extensively developed fans	→ Projects are large scale and often funded through state and federal sources → Continual maintenance is required
Subdivision or localized protection 	Appropriate for moderately developed fans; aims to safely trap debris and route water and sediment around individual residential development	• Debris fences • Grade control • Local channels	→ Smaller scale structures can be more affordable and completed by a private developer → Successful protection plans usually include a combination of elements, allowing for customization	→ A coordinated community plan for all smaller scale efforts must be in place to avoid adverse effects to adjacent properties → Protection plans must prevent development of new flow paths or relocation of existing channels → Periodic maintenance is required

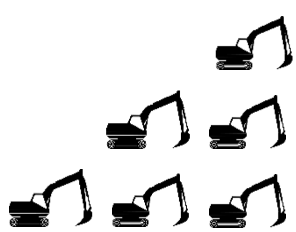
5.3.2 Whole-fan risk management

Permanent structures that intercept flood and debris flows at or above an alluvial fan and transport them around the fan are appropriate for whole-fan risk management. These structures include debris basins, levees, and enhanced channel modifications. Any permanent protective structure that is built will also require a FEMA pre-project Conditional Letter of Map Revision (CLOMR) and a FEMA post-project Letter of Map Revision (LOMR). Both the CLOMR and LOMR will need to be factored into the design and execution of the project. In some areas, FEMA maps may not be available. In that case, it will be important to work with FEMA and the appropriate professionals to initiate a mapping study in that area. Additionally, most projects involving levees will be subject to the National Flood Insurance Program regulations as cited in the Code of Federal Regulations (CFR) at Title 44, Chapter 1, Section 65.10. All levee designs that are 44 CFR 65.10 compliant must be certified by a professional engineer.

The structural risk reduction measures that follow have different price tags and require different levels of maintenance. Below is a key to the relative maintenance requirements and relative construction costs of each structure measure. As you read through the subsequent pages, you can be reference the key to interpret the relative cost and maintenance of different structural risk reduction options.

Key to cost and maintenance of structural risk reduction options

Design and construction cost of a protective structure and resources required for its future maintenance will ultimately be determined during project development. However, relative costs and relative levels of maintenance for different protective structures are offered in this guide as follows:



Maintenance		Cost	
(1 icon)	Low	Low	$
(2 icons)	Mid-level	Mid-level	$ $
(3 icons)	High	High	$ $ $

Debris basin

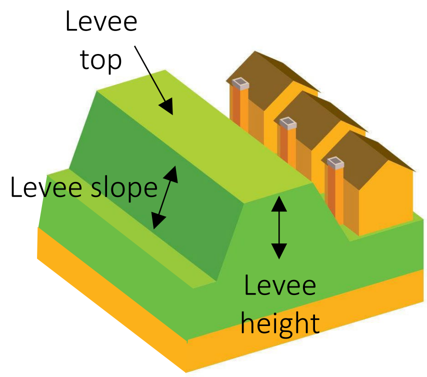
- Definition: Large storage structure located at the upstream portion of an alluvial fan
- Function: Captures and retains both water and sediment
- Design considerations: Debris basin sizing requires consideration of multiple variables, with volume of debris being a key consideration in design
- Maintenance: Requires regular debris removal for basin to perform to design standard

Above: Example of debris basin with outlet structure

Below: Example of debris basin clean-out

Levee

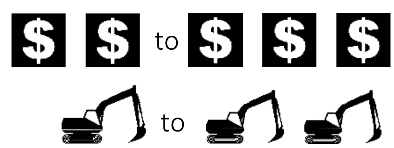
- Definition: Embankment built to prevent the overflow of water
- Function: Directs flow of water to prevents overflows into developed areas
- Design considerations: At a whole-fan scale, the forces exerted on a levee from water and debris likely require the levee to be armored with boulders or a cement lining
- Maintenance: Requires periodic inspection for damage, especially after flood events



Source: https://omaha.com/news/

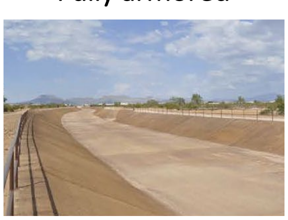
Left: Picture of levee construction in progress; Right: Diagram of levee components

Enhanced channels



- Definition: A channel consists of a bed and two banks and is able to convey water
- Function: Enhanced channels convey water around structures on an alluvial fan
- Design considerations: Depending on the force of water or debris, enhanced channels may range from fully armored with boulders or a cement lining to lined with vegetation; additionally, control measures on the channel slope (also known as grade control) may be required as part of enhanced channel design
- Maintenance: Like levees, enhanced channels require periodic inspection, especially after flood events

Fully armored



Armored side slope
Earth bottom

Earthen channel

Vegetative lining

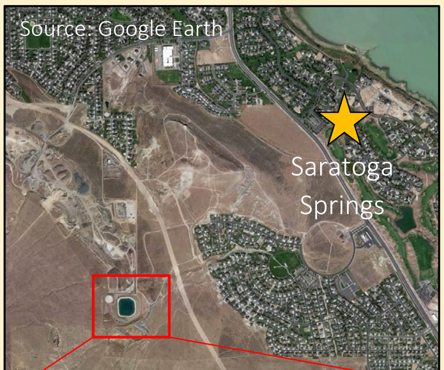
Above: Example of four different enhanced channel types, ranging from fully armored to lined with vegetation.

Example Box 5.3.2: Public Works Department of Saratoga Springs, UT protects the community against alluvial fan flooding.

The community of Saratoga Springs is nestled between Utah Lake and the Lake Mountains. An assessment conducted by the U.S. Army Corps of Engineers (USACE) concluded that there were 14 alluvial fans within the city boundaries.

The unique location of Saratoga Springs (top left, right) puts residents at risk for alluvial fan flooding. Plans to construct a basin to trap debris are part of the city's strategy to manage the unpredictable flooding associated with alluvial fans.

The first debris basin was finished in 2012 (bottom, center and left) and plans for additional structures are ongoing.



5.3.3 Localized or subdivision risk management

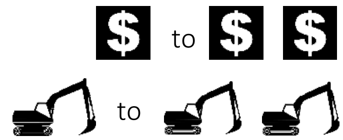
Active alluvial fans that have low to moderate levels of development may benefit from localized risk management. In contrast to fan-wide protective structures, which function to divert all water and sediment around a fan, localized protective structures function to divert flows or debris around a single structure or single development. As a result, localized risk reduction measures can be smaller in scale than those required for whole-fan protection. Protective structures effective at a localized level on an active alluvial fan include debris fences, grade control structures, and reinforced channels

Debris fence

- Definition: Fence-like structure designed to trap debris while allowing passage of water
- Function: Traps debris and absorbs energy of the debris flow
- Design considerations: It is important to anchor debris fences sufficiently to prevent structural failure during a flood or debris flow event on an alluvial fan
- Maintenance: Requires clean-out to function up to design standards, especially after flood events; anchors require inspection for stability and must be repaired if damaged; fence may deform when absorbing force of debris flow, and parts will require replacement after an event

Left: Installation of large boulders (i.e., riprap) to reinforce debris fence anchor base; Right: Picture of exposed debris fence foundation that no longer is protected by riprap after a flood event.

Grade control structure



- Definition: Step-like structure that cascades water from one level to another, preventing it from scouring gullies and channels
- Function: Slows down the speed of moving water and prevents channel erosion, ultimately preventing flows from causing damage to nearby structures or developments
- Design considerations: The number and spacing of grade control structures must be factored into the design process
- Maintenance: Requires periodic inspection for damage, especially after flood events

Above: Example of multi-stepped, multi-tiered grade control structure constructed using gabions, which are wireframe containers that have been filled with rocks

6 Agency support

There are a number of federal and State of Utah government agencies and programs established to support alluvial fan risk management efforts by communities. This section of the guide offers an overview of selected programs that may offer financial support to communities seeking to manage risks associated with alluvial fans. Some government agencies provide technical information to assist communities with their planning efforts. Support for development of this section was provided by the USACE Wyoming Silver Jackets.

State of Utah Assistance

Agency Utah Division of Forestry, Fire and State Lands	**Description** The Division of Forestry, Fire and State Lands Fire Warden will serve as a liaison to the U.S. Forest Service and the Shared Stewardship program, which combines funding from state and federal funding vehicles to address priority forest treatments. Contact the Division Fire Warden in your county to request fuels reduction assistance.
Funding State and Federal	**Website** https://www.fs.usda.gov/managing-land/shared-stewardship https://ffsl.utah.gov/contact/
Agency & Program Utah Department of Natural Resources - *Watershed Restoration Initiative*	**Description** In addition to improving watershed health, the Watershed Restoration Initiative seeks to reduce fuels in high-fire hazard potential areas. By participating in the program, communities work with Habitat Managers and Restoration Biologists with the Division of Wildlife Resources to develop strong plans for fuels reduction projects. Habitat Managers can help seek project funding from multiple funding sources, beyond funds from the Shared Stewardship program.
Funding Varies	**Website** https://watershed.utah.gov/
Agency & Program Utah Department of Public Safety: Division of Emergency Management - *Hazard Mitigation Assistance*	**Description** The Utah Division of Emergency Management's Hazard Mitigation Assistance (HMA) program provides funding for eligible mitigation measures that reduce disaster losses. There are three programs under Utah HMA: • Building Resilient Infrastructure and Communities (BRIC) • Hazard Mitigation Grant Program (HMGP) • Flood Mitigation Assistance (FMA) Visit the state's website below to find out more about each of the three programs listed above.
Funding Varies	**Website** https://hma-utah-em.hub.arcgis.com/

Federal Emergency Management Agency

Program
Community Assistance Program - State Support Services Element (CAP-SSSE)

Description
Funds designated by the state NFIP Coordinator's office to provide technical assistance to communities in the NFIP and evaluate community performance in implementing NFIP floodplain management activities. CAP-SSSE helps to:

- Ensure that NFIP flood loss reduction goals are met.
- Build state and community floodplain management expertise and capability.
- Leverage state knowledge and expertise in working with their communities.

Funding
FEMA regional offices and the designated state agency negotiate a CAP-SSSE agreement that specifies activities and products to be completed by a state in return for CAP-SSSE funds. Nonfederal cost share is 25 percent.

Website
https://www.fema.gov/community-assistance-program-state-support-services-element

National Aeronautics and Space Administration

Program
Applied Sciences Program

Description
Promotes efforts to discover and demonstrate innovative and practical uses of Earth science data and knowledge. Supports and funds applied research and application projects that foster uses of Earth-observing satellite data and scientific knowledge by public and private sector organizations in their policy, business, and management decisions. Applications address disasters (see below), ecological forecasting, health and air quality, water resources, and wildfires.

Funding
Free source of technical information

Website
https://appliedsciences.nasa.gov/

National Oceanic and Atmospheric Administration

Program
Advanced Hydrologic Prediction Services (AHPS)

Description
Provides enhanced hydrologic information, products, and services through the infusion of new science and technology. River forecasts and observations are available at the AHPS website, as well as Precipitation Analysis, Long Range Flood Risk, Probabilistic Forecasts, and Flood Inundation Mapping (FIM). These products and services are provided to assist community leaders and emergency managers in making better life- and cost-saving decisions about evacuations and movement of property before flooding occurs. Please see AHPS User's Guide for description of the suite of graphical and numerical products.

Funding
Technical information 100 percent federally funded. Sponsors asked to contribute $4,000 to help defray NWS FIM costs to host AHPS.

Website
http://water.weather.gov/ahps/

Technical Information
The National Water Model (NWM))

Description
The NWM is a hydrologic modelling framework that simulates observed and forecasted streamflow over the entire continental United States.

Funding
Technical information 100 percent federally funded. NWM output is freely available in various resolutions (1km, 250m, and along a point at a channel or reservoir).

Websites
Download a program brochure here: http://water.noaa.gov/documents/wrn-national-water-model.pdf
Read more about this new cornerstone of the NOAA Water Initiative: http://water.noaa.gov/about/nwm
Learn how to access the information to help gage your watersheds: http://water.noaa.gov/documents/OWP-interface-PDD.pdf

National Weather Service (NWS)

Program
NWS StormReady® Program)

Description
StormReady uses a grassroots approach to help communities develop plans to handle all types of extreme weather-from tornadoes to winter storms. The program encourages communities to take a proactive approach to improving local hazardous weather operations by providing emergency managers with clear-cut guidelines on how to improve their hazardous weather operations.

Funding
Free source of technical information

Website
https://www.weather.gov/StormReady

Program
Weather-Ready Nation Ambassador™

Description
The Weather-Ready Nation Ambassador initiative is the National Oceanic and Atmospheric Administration's (NOAA) effort that formally recognizes NOAA partners who are improving the nation's readiness, responsiveness, and overall resilience against extreme weather, water, and climate events. As a WRN Ambassador, partners commit to working with NOAA and other Ambassadors to strengthen national resilience against extreme weather.

Funding
Free source of technical information

Website
https://www.weather.gov/wrn/ambassadors

Program
NWS National Seasonal Safety Campaign

Description
The aim of the National Seasonal Safety Campaign is to build a Weather-Ready Nation, one that is prepared for extreme weather, water, and climate events. Each campaign includes seasonal resources that provide information that is vital to keeping you and your loved ones safe. These materials include websites, articles, social media, infographics, videos, and other content around the weather hazards most common during the current season.

Funding
Free source of technical information

Website
https://www.weather.gov/safetycampaign

Technical Application
Interactive NWS (iNWS)

Description
Interactive NWS (iNWS) is the home of new mobile and desktop innovations of the National Weather Service (NWS). This application suite delivers NWS products including watches, warnings, and advisories to partners via text and/or e-mail messages and associated mobile-enabled Web pages.

Funding
Free source of technical information

Website
https://inws.ncep.noaa.gov

US Army Corps of Engineers

Program
Floodplain Management Service (FPMS)

Description
FPMS provides technical assistance and planning guidance to federal agencies, states, local governments, other nonfederal entities, eligible tribes, and private sector entities to support effective floodplain management. May include obtaining, interpreting, or developing data about flood sources and types, flood depths and water surface elevations, floodwater velocity, flooding extent and duration, flood frequency, and obstruction of flood flows. Allows for technical assistance only. Cannot conduct site-specific design or fund construction. Silver Jackets is an effort under FPMS to support agency collaboration and coordination with interagency, state-led flood risk and multiple hazard management teams. Provides resources and develops tools to support information sharing and networking, and promotes implementation of flood risk management efforts that improve flood risk awareness and result in actions to reduce risk.

Funding
Services to states, local governments, and eligible tribes are 100 percent federally funded. Nonfederal sponsor may voluntarily contribute funds to expand scope of services per Section 202 of the Water Resources Development Act (WRDA) of 1999. Services to federal agencies and the private sector are provided on a 100 percent cost recovery basis.

Websites
FPMS:
https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/
Silver Jackets:
http://silverjackets.nfrmp.us/

Program
Engineering with Nature (EWN)

Description
USACE's Engineer Research and Development Center maintains a repository for projects that align natural and engineering processes. With recent advances in the fields of engineering and ecology, opportunities exist to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management. See "Engineering with Nature: An Atlas" Volumes I and II at the website below for more information and examples.

Funding
Free source of technical information and case studies.

Website
https://ewn.el.erdc.dren.mil/index.html

US Army Corps of Engineers (continued)

Program
Continuing Authorities Program (CAP)

Description
CAP authorizes feasibility study and construction for relatively small projects; it usually requires no further congressional authorization to proceed to construction. Under this umbrella, the Emergency Stream Bank and Shoreline Protection (Section 14, Flood Control Act of 1946, as amended) authority allows emergency stream bank and shoreline protection to prevent damage to public facilities, such as roads, bridges, hospitals, schools, and water/sewage treatment plants. Maximum federal expenditures are limited to $5 million. CAP's Flood Damage Reduction (Section 205, Flood Control Act of 1948, as amended) authority provides for construction/improvement of flood risk reduction works (levees, channels, and dams) for local flood protection. Non-structural alternatives may include measures such as flood warning systems, raising and/or floodproofing structures, and relocation of flood-prone facilities. Maximum federal expenditures are limited to $5 or $10 million depending on the authority.

Funding
Feasibility Study: First $100,000 is federally funded. Remaining costs are shared at 50 percent federal, 50 percent nonfederal.
Design & Construction: Cost shared at 65 percent federal, 35 percent nonfederal. Nonfederal sponsor's cost share may include cash and work-in-kind.

Website
https://www.nae.usace.army.mil/missions/public-services/continuing-authorities-program/

Program
Planning Assistance to States (PAS)

Description
The PAS program (Section 22, WRDA 1974, as amended) assists states, local governments, tribes, and other nonfederal entities with preparation of comprehensive plans for development, utilization, and conservation of water and related resources of drainage basins, watersheds, or ecosystems. Provides technical assistance in support of state (or groups of states) water resources management and related land resources as identified in state water plans or hazard mitigation plans; preparedness, response, and recovery plans; or plans associated with changing hydrologic conditions, climate change, long-term sustainability, and resilience. Studies are for project planning and may not include preparation of site-specific designs. Construction is not included.

Funding
Cost shared at 50 percent federal, 50 percent nonfederal. Nonfederal sponsor's cost share may include cash and work-in-kind.
Limited to $5 million federal funds per state in a fiscal year. Limited to $2 million federal funds per state per fiscal year for cooperative agreements with nonprofit organizations to assist rural and small communities.

Website
https://www.nae.usace.army.mil/missions/public-services/planning-assistance-to-states/

U.S. Department of Agriculture

Program	Description
Agricultural Conservation Easement Program (ACEP)	ACEP (Farm Bill of 1985, as amended) provides financial and technical assistance to help conserve agricultural lands, wetlands, and their related benefits. The Wetland Reserve Easement component is a voluntary program offering landowners an opportunity to protect, restore, and enhance wetlands on their property and to establish long-term conservation and wildlife practices and protection. The goals are to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every enrolled acre. In many cases, restoration and protection of wetlands also reduce flood damages.
Funding	**Website**
For permanent wetland easements, NRCS pays 100 percent of easement value and up to 100 percent of restoration costs.	http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep/c

U.S. Department of Transportation

Agency	Description
Federal Highway Administration	Provides a variety of funding sources, including both grants and loans, to state, local, and tribal governments for the development of transportation systems.
Funding	**Website**
Cost sharing depends on the program.	https://www.fhwa.dot.gov/resources/topics/funding.cfm

U.S. Geological Survey

Program	Description
Cooperative Matching Funds	Provides federal funds to match offerings from some 1,600 local, state, and tribal agencies for select USGS stream gages and interpretive projects. Funds are allocated through various programs, and priorities are informed through discussion with state and local partners.
Funding	**Website**
As much as 50 percent federally funded.	https://www.usgs.gov/mission-areas/water-resources/science/usgs-cooperative-matching-funds