Risk Assessment and Recommendation Report

Landslide at Cook Lake

Bearlodge Ranger District
Black Hills National Forest

View of the Cook Lake Area, looking northwest, showing the relative sizes and positions of the lake and slide complex. National Forest Service Road 842 is in the foreground.

Prepared for:
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RISK ASSESSMENT and RECOMMENDATION REPORT for a LANDSLIDE at COOK LAKE

Signature Page

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RISK ASSESSMENT and RECOMMENDATION REPORT for a LANDSLIDE at COOK LAKE

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1.0 Introduction

The Cook Lake Recreation Area is located in the Bearlodge Mountains in northeast Wyoming on the Bearlodge Ranger District of the Black Hills National Forest. The recreation area is located around the reservoir of Cook Lake Dam, a Forest Service managed dam. A known landslide area exists on the hill on the west side of the reservoir. The concern is that slide activity could potentially cause injury or death to the visitors in portions of the recreation area. The Black Hills National Forest formed a Risk Assessment Team comprised of engineers, a geologist, and recreation specialists to conduct a risk assessment and provide this report with the analysis and recommendations.

2.0 Purpose

The purposes of this assessment and recommendation report are to:
1) Assess the landslide risk to Forest visitors in the Cook Lake Recreation Area;
2) Assess the risk to their personal property; and
3) Provide risk mitigation recommendations and site-operating management recommendations for consideration - so Forest Service decision makers may choose among, supplement, modify, and apply the recommendations to manage the Cook Lake Recreation Area.

While the risks associated with using developed recreation sites are generally low, there is potential for the presence of unique or unusual hazards that may not be readily apparent to facility users. There are six commonly identified hazards at Forest Service sites nationwide:

- Flooding/flash flooding/dam failures above sites
- Hazardous forest conditions
- Wildfire
- Wildlife (bears, cougars, snakes)
- Landslides & rock fall
- Steep drop-offs, waterfalls, & cliffs

This report analyzes two of the commonly identified hazards: flooding/flash flooding/dam failures above sites and landslides & rock fall.

This report addresses:

- the need for good decision making in a developed recreation facility that is in or near a flood or geological hazard;
- the need for warning signs;
- the need for adequate communication capabilities;
- the need for training on the potential hazards and emergency actions for campground hosts and workers;
- the need for informed Forest Service workers;
- the need for rapid exit from remote recreation sites;
- improving emergency notification and action plans; and
- a plan for informing the public about the limited re-opening and the overall status of the area. (Recreation Visitor Safety Report, 2010.)

3.0 Background

The Cook Lake Dam and Recreation area is on Beaver Creek, a tributary of the Belle Fourche River. Wyoming Highway 24 is about 9 miles downstream from the dam. The reservoir holds 330 acre-feet with a surface area of 31 acres. (Comprehensive Dam Evaluation, 2009.)
The Wyoming Game and Fish Commission (WGFC) built Cook Lake Dam in 1940-41 to provide a recreational opportunity for fishing and other water-recreation activities in a mountain setting. By April of 1941 the State Engineer approved a 5-foot increase in the dam's height nearly doubling the proposed lake's capacity. (Survey in Support of the Cook Lake Recreation Facility Maintenance, 2014.)

A flood in 1962 partially breached the dam. The breach resulted in a feasibility report in 1964 which documented the beginning of another series of changes to the Cook Lake Recreation Area. Then the WGFC lacked funds for repairing the dam to the Forest Service standards. The WGFC offered to share the costs with the Forest Service, with the Forest Service assuming responsibility for the dam and revoking the WGFC's special use permit for the dam. The parties finalized the agreement in 1965. Engineers repaired the dam using Forest Service specifications and the present spillway was complete by 1969. (Survey in Support of the Cook Lake Recreation Facility Maintenance, 2014.)

In 1995, 2007, 2011 and 2014, high water levels in Cook Lake nearly exceeded the spillway culvert capacity – highlighting the deficiencies of the dam and spillway. The 2007 flows led to the Forest Service consulting with the Bureau of Reclamation for a Comprehensive Dam Evaluation on Cook Lake Dam, 2009.

The Forest Service identified needed improvements for the Cook Lake dam and capital improvement funds are currently available to improve the spillway and outlet works. The Forest Service is currently working with the Bureau of Reclamation to address and complete those improvements with the anticipated completion by 2019.

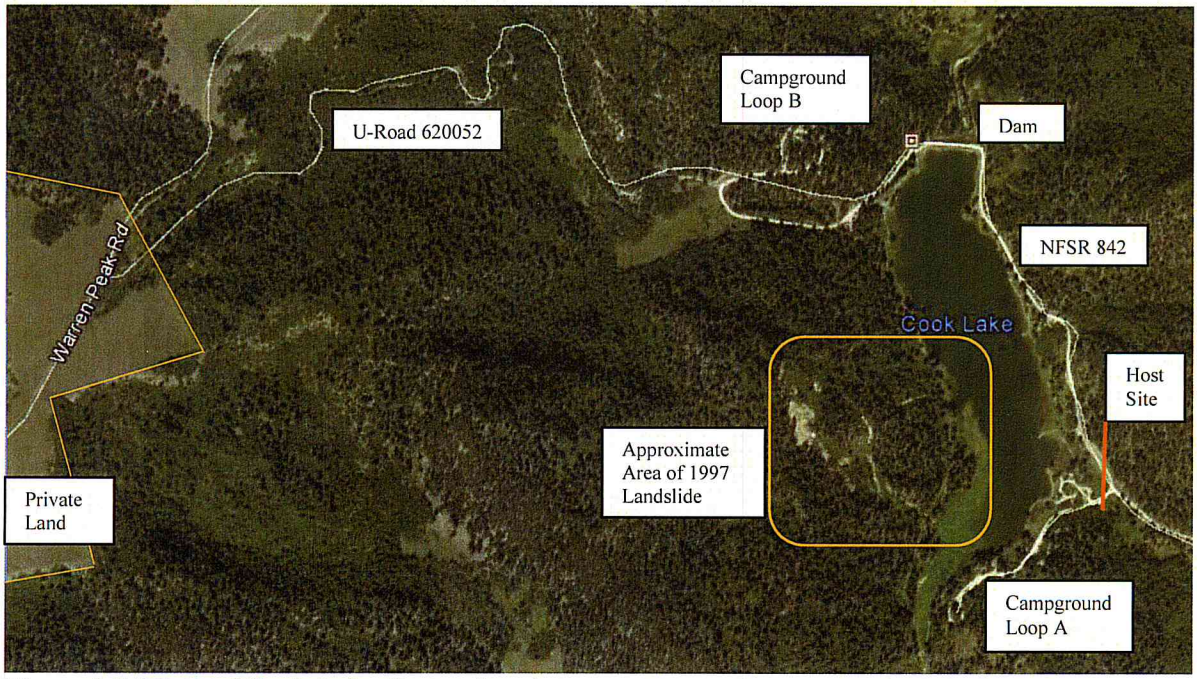


Figure 3.0 View of Cook Lake Recreation Area

The Forest Service completed many improvements through the years, and today the recreation area has a campground with Loops A and B, having 19 and 15 sites, respectively. The host site is in Loop A, near the area's entrance. The recreation area includes 33 picnic sites, a portable dock for non-motorized boat launch, two water hydrants, and four toilet facilities. Two trailheads are in the area: the Cook Lake Trailhead (Trail 88) – Trail 88 circles Cook Lake, and the Cliff Swallow Trailhead (Trail 91). (Campground Concession Prospectus, 2014.) Cook Lake Recreation Area is a popular recreation site that is often over capacity during the summer holidays and at or near capacity on many weekends. The area provides highly desirable reservoir recreation in a mountain setting providing for climate relief from the surrounding plains. The only other reservoir recreation opportunity in Crook County is about 40 miles southwest at Keyhole Reservoir, which is in a semi-arid prairie setting.

4.0 Issues

Many historic and active landslides surround Cook Lake in the Bear Lodge Mountains, north of Sundance in Crook County, Wyoming. Several slope failures occurred in the last 70 years; the most recent was in 1997. The 1997 event involved the slide of a 27-acre area on the southwest side of Cook Lake. Following a two-year period a record rainfall for Crook County, soil saturation levels were likely high enough in a subsurface clay layer to lead to a failure and the initiation of this complex slide. For additional information see; Cook Lake Landslide Stability Analysis, 2016.

Informed concern of the landslide potential near Cook Lake grew after the 1997 slide. The concern was heightened even more with three recent landslides in the US which resulted in damage and fatalities: Oso, Washington (April 2014 - 43 deaths); Bingham Canyon, Utah (2013 - 5.5 times larger than the Oso slide yet resulted in no deaths); and Salt Creek, Colorado (2014 - 3 deaths). The Oso Landslide was in an area of known landslides. The 2014 Oso slide was larger, traveled further, and was more destructive than earlier Oso-area landslides. The landslide's mobility was due to contributing factors, including the soil's porosity and water content from earlier rainfall. Precipitation at Oso was 200% above the average in the two months preceding the landslide, thus contributed to landslide re-initiation and mobility. The Oso landslide would likely have moved slower and with less volume if the soil were drier and less dense. The Forest Service's landslide observations at Cook Lake and their knowledge of the hazards from landslides resulted in a temporary closure of Cook Lake. The Forest Service sought a stability analysis from the Colorado School of Mines and a review of their emergency process.

The possibility of death or injury to people in the Cook Lake Recreation Area, or loss or damage of property caused by the landslide is a likelihood if they are caught in the sliding earth or mudflow. Above average to well above average rainfall, over a period of time or in a single event usually triggers landslides. The soil super-saturates –including the soil's subsurface layers. The super-saturation lowers the strength of the underlying materials so that they eventually rotate or flow under their own weight. Gravity with the weight of overlying material then displaces the semi-liquefied soil until it finds an equilibrium at a lower elevation. Not all slides are alike. Most of those in the Cook Lake area rotate in a step-like fashion, while others undergo fluid flow such as the Oso slide, but there is complete gradation between the two types. Oso previously, was a rotational slide but transitioned to a fluid flow after the above average precipitation. The precipitation in the Oso slide-area was 200% above its average – indicating the super-saturation of soils which contributed to the failure. The Cook Lake Stability Study concluded, in part, that, "water table variations have less of an influence at Cook Lake than is typical for landslides.

Changed loading conditions, driven by the post-slide topography, are more influential." (Cook Lake Landslide Stability Analysis, 2016.)

Soil saturation may stay in an area with above normal rainfall for many months. 1997, the year of the latest slide at Cook Lake, was a year of average rainfall. In the years leading up to the 1997 slide, three of the years were within the average, and two were high (1993 and 1995). So although a year may be average, or even below average, in surface precipitation, the ground may still have high saturation levels (See Appendix B).

4.1 Condition of the dam

The dam is a homogenous earth fill embankment 37 feet and 400 feet long with a graveled crest. The spillway is four 6-foot diameter corrugated metal pipes that are each 110 feet long. The dam surface is in serviceable shape. The spillway's discharge capacity of 1,420 cubic feet per second, and the emergency spillway's discharge capacity of 470 feet per second, are significantly below the recommended capacity of 15,000 cubic feet per second to accommodate one-half of a probable maximum flood. In the event of receiving an actual flood at or near the probable maximum flood scenario probable results could include: water may over-top the dam, debris may clog the spillway and thus lead to potential dam failure (Comprehensive Dam Evaluation, 2009 and Emergency Action Plan: Cook Lake Dam, 2014.)

4.2 Ingress and egress of campground Loop B

National Forest Service Road (NFSR) 842 is the only authorized motorized ingress and egress to Cook Lake Recreation Area. NFSR 842 passes over the top of the dam and provides access to Loop B. In past high precipitation events, the Forest temporarily closed Loop B and facilities on the west side of the lake as a precaution when the lake level was rising and approaching the capacity of the spillway. The Forest took these actions to pro-actively preclude stranding Forest visitors on the lake's west side in the event that water overtopped the dam. (Emergency Action Plan: Cook Lake Dam, 2014.)

NFSR 842 continues west for 530 feet from the turn-off approach to Loop B, extending behind a gate where the District has a small supply yard. Beyond the end of NFSR 842, an unauthorized road (U-road 620052) runs further west for 1.1 miles, providing access to the graveled Warren Peak Road, also known as Crook County Highway 63 on the Taylor Divide. U-road 620052 was the original, and at the time the dam was built, circa 1941, the only road to Cook Lake. The Forest Service built NFSR 842 in the mid-1970s or early 1980s and then abandoned the original access that is now U-road 620052.

4.3 Communications to Cook Lake Recreation Area

Communication is available via radio and satellite. Cellular Service or land line telephone are not available in the area. As supported by the Cook Lake Dam Emergency Action Plan the Forest Service has been providing a radio to the Cook Lake Campground Host. The Host used this radio in 2009 to contact emergency services when trees felled by a tornado made the roads impassable to access or depart from Cook Lake. There is a fiber optic cable providing service to a private residence about 1.5 miles west northwest of the dam.

Current Conditions for the Cook Lake Recreation vicinity

The vicinity around Cook Lake has remained open for public access. The Bearlodge Mountains receive a lot of big game hunting pressure as well as winter over snow vehicle use. The Cook Lake Emergency Closure Order even left areas adjacent to Forest Road 114 (Farrall Road) open to dispersed camping even though they were within the closure area. Although Cook Lake has

been closed, there have been many incidents where people walked in to use the area in violation of the closure order. Infrastructure has been left in place during the closure including tables, benches, water systems, trails, fishing piers, toilets, etc. and have been maintained.

5.0 Identify the Risk

5.1 Landslide to campground Loop A

The threat to people at Cook Lake Recreation Area varies in different parts of the recreation area. The greatest threat exists to people in campground Loop A, particularly sites 1 - 6. The campground host site is the furthest from the landslide in Loop A, next to the entrance and NFSR 842, and may be at somewhat less risk than sites closer to the lake. In four of the five models run by the geological researchers on a potential new slide showed no effect from a landslide runout on Loop A. Yet researchers found that one model run showed that a best-fit trend line for landslide runout into A Loop was within the model's confidence intervals so "must still be considered". The modeled run that does come across the lake was used as the potential area to impact in this report due to the unknown force and extent of the landslide when it does slide. The team used this scenario because a slide of this magnitude is predicted to have the most possible impact. (Cook Lake Landslide Stability Analysis, 2016, Section 5.0 and Section 5.5.)

5.2 Landslide to campground Loop B

Cook Lake's eastern shore has most of the picnic sites and is, along with the campground's Loop B, thought by the geological researchers to be of a lower risk from the landslide than those on the west side of the lake. Loop B, several picnic sites, Cliff Swallow Trailhead, and Trail 91 are on the west side of Cook Lake. The picnic sites on the lake's north side, adjacent to NFSR 842, and two picnic sites on the lake's northwest side along with two benches near the lake are also predicted to be at less risk. Forest users access the west side facilities via graveled NFSR 842 that runs on the top of the dam. Geological researchers' five potential landslide runout models showed no effect on the east side picnic sites, Loop B and the north and northwest picnic sites. (Cook Lake Landslide Stability Analysis, 2016.)

5.3 Landslide to the west segment of the Cook Lake Trail

The greater risk to loss of life or property damage from a landslide is on the west side of Cook Lake - including the west segment of the Cook Lake Trail (Trail 88), which circles the lake. The trail, a pedestrian bridge, a gate, and a buck-and-rail fence are near the toe of the landslide. Geological researchers recommended no longer using the recreation facilities near the toe of the landslide. The stability study concluded, in part, that "future failures will likely only reactivate a portion of the 1997 slide and involve smaller volumes." The study continued, "[t]he slide may fail rapidly and could create hazards on trails crossing the slide." (Cook Lake Landslide Stability Analysis, 2016.)

5.4 Landslide threat to dam by water and by earth

The primary threats to the Cook Lake Dam are from high water flow from precipitation and the potential impacts of a large scale landslide movement into the lake. In both cases, the resulting rise in water level and its effects on the dam's overflow structures are the principle issues of concern. Infilling of the lake by rock and mud from a landslide during saturated conditions concurrent with a precipitation event that had already raised water levels of the lake would pose the greatest risk to the dam. If a landslide occurred during such an event, and all or a portion of the slide material runs into the lake, it could cause the water level to rise, perhaps overtopping the dam, and contributing to dam failure. (Comprehensive Dam Evaluation, 2009.)

Landslide-related mobilization of the dam's western abutment, independent of any threats from the spatially separate failure on the lake's southwest, is also a potential threat to the dam. The Cook Lake Dam is in a narrow canyon in the Beaver Creek drainage. The site is primarily underlain by a series of older landslides. The specific landslide on which the western dam abutment sits was mobile in the mid-1960s. (See also: Survey in Support of the Cook Lake Recreation Facility, 2014; and the Comprehensive Dam Evaluation, 2009.)

6.0 Assess/Analyze the Risk

6.1 Conditions for Analysis

Precipitation	Landslide State	Soil Saturation	Dam Failure	Earthquake
-Below Average -Average -Above Average -High Single Event	-Meta-stable Slow Rate of Movement -Occasional Movement -Unstable -Frequent Movement at Faster Rate	-Dryer than average and/or drying trend -Average saturation and/or trend not changing -Average saturation and/or trending wetter -Above average saturation and/or trending wetter	Rapid drawdown of reservoir causes increase in shear stress in landslide area	Causes unstable conditions in landslide

Table 6.1- Conditions

6.2 Scenarios. As stated previously landslides are influenced by the amount of precipitation received in the local area and the amount soil saturation within the landslide itself. Larger more catastrophic landslides often have soil/debris movement within the slide prior to the more major movement. The Risk Assessment Team developed nine different scenarios each with varying levels of precipitation, landslide movement, and landslide saturation then assessed the level of risk for each scenario.

Scenario	Precipitation	Landslide Movement	Landslide Saturation
1	Below Average	Meta-stable	Dryer than Average
2	Average	Meta-stable to Slow	Average
3	Average	Slow to Occasional	Average
4	Average	Frequent/Unstable	Average
5	Above Average	Meta-stable to Occasional	Above Average
6	Above Average	Frequent /Unstable	Above Average
7	High Single Rain Event	Occasional/Frequent	Any Saturation Level
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/slow/Frequent/Unstable	Average
9	Earthquake	Meta-stable/slow/Unstable	Any Saturation Level

Table 6.2 - Scenarios

6.3 Measure of Likelihood

Based upon the known information about the Cook Lake Landslide and area surrounding it, each scenario will then have a Measure of Likelihood applied.

Level	Descriptor	Description
A	Almost Certain	Expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	May occur in some circumstances
D	Unlikely	Unlikely to occur in most circumstances
E	Rare	May only occur in exceptional circumstances

Table 6.3- Measure of Likelihood

6.4 Measure of Consequence of Impact

Based upon the fact that a landslide does exist above Cook Lake, a Measure of Consequence will then have a level applied in the event a landslide does occur.

Level	Descriptor	Detail of Description
1	Insignificant	No injuries, little or no damage, low financial loss
2	Minor	First aid treatment, minor damage, medium financial loss
3	Moderate	Medical treatment required, moderate infrastructure damage, high financial loss
4	Major	Extensive injuries, high level of infrastructure damage, major financial loss
5	Catastrophic	Deaths, most facilities extensively damaged and major infrastructure failure, huge financial loss

Table 6.4 – Measure of Likelihood

6.5 Risk Analysis Matrix – Level of Risk

The result of the Measure of Likelihood and the Measure of Consequence are then placed in the following Risk Analysis Matrix to determine the Level of Risk for each scenario.

Likelihood	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A Almost Certain	High	High	Extreme	Extreme	Extreme
B Likely	Moderate	High	High	Extreme	Extreme
C Possible	Low	Moderate	High	Extreme	Extreme
D Unlikely	Low	Low	Moderate	High	Extreme
E Rare	Low	Low	Moderate	High	High

Table 6.5 – Level of Risk

7.0 Evaluate the Risk

7.1 Assumptions.

7.1.1 The following analyses uses the information available at this time.
7.1.2 The Forest Service will gather quantitative information from the monitoring efforts identified in the mitigations section of this assessment.
7.1.3 This landslide assessment recognizes that it concerns a relatively small, discrete, wholly federally managed land base. Thus, the Forest Service holds an increased ability to reasonably control the risk. This contrasts with the Bureau of Reclamation's Cook Lake Dam Comprehensive Report which had to assess downstream risks in the Beaver Creek watershed to private property, private human dwellings, the public travel on Wyoming Highway 24, and the town of Alva – places where the Forest Service alone cannot reasonably control that risk.
7.1.4 The Forest Service built a recreation site in an area that now has known risk and the purpose of this site is purely for recreational enjoyment. Although recreation is very important, and Cook Lake is unique in the immediate area that it is located, other similar recreational opportunities are available within an hour drive. This risk assessment is based on a discretionary need. No one lives or works at Cook Lake or depends on its opening for their basic life needs.
7.1.5 We have used the "worst case scenario" to analyze risk and consequences for this assessment. Slides may occur that are not as severe or consequential as we are analyzing in this report.
7.1.6 Even though a major move of the landslide may be unlikely at any given moment, the potential for it is present at all times.
7.1.7 The sub-surface saturation data is generalized from previous years precipitation generally classified as below, average, or above average. In the future, the recommendation is for the agency to install monitors to yield quantitative saturation data.

7.2 Ground Movement Indicators and Triggers.

7.2.1 Metastable. Metastable indicates that a zone is at temporary state of equilibrium, but it has the potential to move with changing conditions. It does not indicate total stability.
7.2.2 Slow Movement. Slow movement indicates values in the range of inches per year rather than feet per year.
7.2.3 Unstable. Unstable indicates movement that is measured in feet per year or more and constant motion.
7.2.4 Occasional Movement. Occasional movement means that measurement is periodically measured in inches per year, but is interrupted by periods of non-movement; i.e. this means that a very slow stop and start behavior. The intervals of movement and quiescence are multiple months in duration
7.2.5 Frequent Movement. Frequent movement indicates movement that aggregates in feet per year movement that is punctuated by short periods of quiescence measure in days rather than months.
7.2.6 Landslide saturation. Landslide saturation, which related to subsurface pore pressures (Deep soil moisture), is included as it is a critical component of risk assessment. We do not currently have a baseline for this measurement, as it requires piezometers to be installed, which has not occurred to date. When measurements are

available, they will be an essential part of the ongoing risk assessment and monitoring process. Since the soil saturation data that we currently have is limited, the Measure of Likelihood based more heavily on precipitation received and slide movement.

7.3 Initial Evaluation with no mitigation. The initial evaluation (and condition prior to closing the lake in 2014) of the Cook Lake Recreation Area operational status has Loop A open to camping, Picnic Area open, Loop B open to camping. There would be no landslide monitoring or special landslide procedures in place.

Scenario	Precipitation	Landslide Movement	Landslide Saturation	Risk Level
1	Below Average	Meta-stable	Dryer than Average	E5- High
2	Average	Meta-stable to Slow	Average	D5- Extreme
3	Average	Slow to Occasional	Average	D5- Extreme
4	Average	Frequent/Unstable	Average	D5- Extreme
5	Above Average	Meta-stable to Occasional	Above Average	C5- Exteme
6	Above Average	Frequent /Unstable	Above Average	B5- Extreme
7	High Single Rain Event	Occasional/Frequent	Unknown/Not Applicable	C5- Extreme
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/slow/Frequent/Unstable	Average	C5- Extreme
9	Earthquake	Meta-stable/slow/Unstable	Unknown/Not applicable	B5- Extreme

Table 7.3 Scenarios

8.0 Mitigations

8.1 Reduce Exposure

8.1.1 (Temporary) Closure Order

The Black Hills National Forest enacted a temporary closure order on Cook Lake Recreation Area in May of 2014. The Forest needed the time provided by two closure orders to request and then complete a landslide stability analysis and gave the Forest Service the decision space to review results of the stability analysis and the adequacy of the Forest's and Crook County's Cook Lake Dam Emergency Action Plan. Forest resource work was the only authorized access in the Area during the closure – with the exception of January to early March of 2015 when the Forest Service allowed day-use access predominately for ice fishing. This was a low risk access since it is rare for landslides to manifest when the ground is frozen.

8.1.2 Close the west segment of Cook Lake Trail (Trail 88), one pedestrian bridge, lock gates, and erect fence

For visitor safety, the Forest Service may re-route Cook Lake Trail (Trail 88) away from the toe of the landslide and ensure that Trail 88 would no longer circle the lake. Segments of Trail 88 on the lake's north, northwest, east, and south sides remain useable as well as the Trailhead. The agency should also remove improvements from the lake's southwest side which could entice visitors onto the area with the greater risk. The Forest Service should retain the 3 small pedestrian bridges on the northwest segment of Trail 88, so agency workers can access and maintain the off-limits fencing without having to wade, and so the public may access two extreme northwest picnic sites and benches – all north of the potential renewed landslide area or the toe-area of the existing landslide. The agency should also publish and post a Forest Closure Order, erect signs, and fencing creating an off-limits area at the toe of the landslide and enforce the Closure Order. (Cook Lake Landslide Stability Analysis, 2016.)

8.2 Introduction of Controls

Given the above baseline or initial evaluation, we then determined controls that are readily or near-term available to reduce the exposure of people to the landslide risk. These controls generally are in the following groups:

- Reduce the exposure of people to the risk through closure orders and fencing. The agency may choose to have some areas available for day-use only when people are prone to be alert to changes in their surroundings, as contrast to the limited visibility of darkness or the unconsciousness of sleep. This control stands alone without other controls.

- Increase knowledge of this landslide through monitoring and data collection/analyzation including surface precipitation and sub-surface soil saturation and its potential effect on this landslide ability to control adequate communication with people in the recreation area.

8.3 Monitoring Options

- Visual Inspection - on and around the slide area for noticeable visual changes
- Survey points – Manpower required to check
- Survey points – Real time data transfer - through use of remote telemetry
- Survey points with trigger cables - Real time data transfer, through use of remote telemetry
- Lake level/dam condition – Visual inspection
- Lake level – Real time data transfer, through use of remote telemetry

8.4 Management Options/Area Status/Operational Controls

The Risk Assessment Team then developed seven Management Options that each vary the amount of exposure of the people who recreate/work at the Cook Lake Recreation Area.

- Management Option 1, Cook Lake Recreation Area CLOSED
- Management Option 2, Loop A Camping, Picnic Area open – Loop B Camping, Trail 88 CLOSED
- Management Option 3, Loop A Day Use, Picnic Area open, Loop B Camping, Trail 88 CLOSED

- Management Option 4, Loop A CLOSED, Picnic Area open, Loop B Camping, Trail 88 CLOSED
- Management Option 5,Loop A CLOSED, Picnic Area CLOSED, Loop B Camping, Trail 88 CLOSED
- Management Option 6, Loop A Day Use, Picnic Area Open, Loop B Day Use, Trail 88 CLOSED
- Management Option 7, Loop A CLOSED, Picnic Area Open, Loop B Day Use, Trail 88 CLOSED

Notes: the campground host site, currently in Loop A, may remain in its location as its location is partially protected by the elevation gain from the lake. This is the best location for control of public access and uses in Loop A. The notation above in management options 2-7, "Trail 88 Closed" refers to the segment of the trail in areas subject to a closure order. Trail 88's segments outside a closure area remain open. The Risk Assessment Team intends the management options as guidelines on which to frame a reasonable risk assessment and a tool to use for decision making to the Authorized Officer.

9.0 Evaluate the Risk with Controls

9.1 Management Option 1

Management Option 1, Cook Lake Recreation Area CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E1 – Low
2	Average	Meta-stable to Slow	Average	D5-Extreme	E1 – Low
3	Average	Slow to Occasional	Average	D5-Extreme	E1 – Low
4	Average	Frequent/Unstable	Average	D5-Extreme	E1 – Low
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	E1 – Low
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	E1 – Low
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	E1 – Low
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/ slow/Frequent/Unstable	Average	C5-Extreme	E1 – Low
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	E1 – Low

Table 9.1

The residual risk level to people is low in this option since people are not exposed to the risk.

9.2 Management Option 2

Management Option 2, Loop A Camping, Picnic Area open – Loop B Camping, Trail 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E5- High
2	Average	Meta-stable to Slow	Average	D5-Extreme	D5-Extreme
3	Average	Slow to Occasional	Average	D5-Extreme	D5-Extreme
4	Average	Frequent/Unstable	Average	D5-Extreme	D5-Extreme
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	C5-Extreme
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	B5-Extreme
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	C5-Extreme
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/ slow/Frequent/Unstable	Average	C5-Extreme	C5-Extreme
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	B5-Extreme

Table 9.2

9.3 Management Option 3

Management Option 3, Loop A Day Use, Picnic Area open, Loop B Camping, Tr 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E2- Low E3-Moderate
2	Average	Meta-stable to Slow	Average	D5-Extreme	D3- Moderate
3	Average	Slow to Occasional	Average	D5-Extreme	D3- Moderate
4	Average	Frequent/Unstable	Average	D5-Extreme	D4- High
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	D4- High
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	C3-High
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	C3-High
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/slow/Frequent/Unstable	Average	C5-Extreme	C4-Extreme
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	B4-Extreme

Table 9.3

9.4 Management Option 4

Management Option 4, Loop A CLOSED, Picnic Area open, Loop B Camping, Tr 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E1 – Low
2	Average	Meta-stable to Slow	Average	D5-Extreme	E1 – Low
3	Average	Slow to Occasional	Average	D5-Extreme	E1 – Low
4	Average	Frequent/Unstable	Average	D5-Extreme	E2 – Low
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	E2 – Low
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	B2-Moderate
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	E1-Low
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/slow/Frequent/Unstable	Average	C5-Extreme	C3-High
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	B4-Extreme

Table 9.4

9.5 Management Option 5

Management Option 5, Loop A CLOSED, Picnic Area CLOSED, Loop B Camping, Tr 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E1 – Low
2	Average	Meta-stable to Slow	Average	D5-Extreme	E1 – Low
3	Average	Slow to Occasional	Average	D5-Extreme	E1 – Low
4	Average	Frequent/Unstable	Average	D5-Extreme	E1 – Low
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	E1 – Low
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	B2-Moderate
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	E1-Low
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable /slow/Frequent/Unstable	Average	C5-Extreme	C3-High
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	B3-High

Table 9.5

9.6 Management Option 6

Management Option 6, Loop A and Picnic Area - Day Use, Loop B Day Use, Tr 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E2- Low E3-Moderate
2	Average	Meta-stable to Slow	Average	D5-Extreme	D3-Moderate
3	Average	Slow to Occasional	Average	D5-Extreme	D3-Moderate
4	Average	Frequent/Unstable	Average	D5-Extreme	D4- High
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	D4-High
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	C3-High
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	C3-High
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/ slow/Frequent/Unstable	Average	C5-Extreme	C4-Extreme
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	B4-Extreme

Table 9.6

9.7 Management Option 7

Management Option 7, Loop A CLOSED, Picnic Area Open, Loop B Day Use, Trail 88 CLOSED					
Scenario	**Precipitation**	**Landslide Movement**	**Landslide Saturation**	**Initial Risk Level**	**Residual Risk Level**
1	Below Average	Meta-stable	Dryer than Average	E5- High	E1 – Low
2	Average	Meta-stable to Slow	Average	D5-Extreme	E1 – Low
3	Average	Slow to Occasional	Average	D5-Extreme	E1 – Low
4	Average	Frequent/Unstable	Average	D5-Extreme	E1 – Low
5	Above Average	Meta-stable to Occasional	Above Average	C5-Exteme	E1 – Low
6	Above Average	Frequent /Unstable	Above Average	B5-Extreme	B2-Moderate
7	High Single Rain Event	Occasional/Frequent	Any saturation level	C5-Extreme	C2-Moderate
8	High Single Rain Event/Threat to Dam Imminent	Meta-stable/slow/Frequent/Unstable	Average	C5-Extreme	C3- High
9	Earthquake	Meta-stable/slow/Unstable	Any saturation level	B5-Extreme	C3- High to C4- Extreme

Table 9.7

10.0 Residual Risk

The summary table shows residual risk after the implementation of the mitigation and/or controls. Presently the monitoring of the landslide includes visual inspection and a re-survey of the monuments. It does not include advanced landslide monitoring technologies that are not yet in place. Currently the Forest Service monitors precipitation, known and forecast, and makes generalized qualitative hypothesis of landslide sub-surface soil saturation based on precipitation from previous years. The Forest Service is actively monitoring the lake level.

To determine an overall Level of Risk by Management Option, the number of low, moderate, high and extreme risk for each scenario were then summed up. The Risk Assessment Team then discussed each Management Option and assigned an overall Risk Level. The overall Risk Level was large determined by the majority number but was and can be influenced the different levels of risk within the Management Option (i.e. If a management option were to contain High and Low risks but a majority number of Low Risks, that particular option could potential be rated as a moderate risk.).

Management Options/Controls	Number of Low	Number of Moderate	Number of High	Number of Extreme
1	9	0	0	0
2	0	0	1	8
3	0	3	4	2
4	6	1	1	1
5	6	1	2	0
6	0	3	4	2
7	5	2	2	0

Low Risk Moderate Risk High Risk Extreme Risk

Table 10.1 – Summary of Levels of Risk by Management Option

11.0 RECOMMENDATIONS

11.1 Determine the Alternative for Future Management.

11.1.1 Past management without greater mitigation. This alternative would be to manage the Cook Lake Recreation Area with the past management used at the area. This option does not make the best use of new information and new technology to assist the Forest Service with risk assessments and management decisions.

11.1.2 Reduce Exposure, Reduce the Level of Risk.

11.1.2.1 Implement a Forest Closure Order on the landslide area on the southwest side of Cook Lake, posting the order and fencing the lakeside accesses.

11.1.2.2 Use the Management Option Matrices as a tool in selecting a Management Option for Cook Lake Recreation Area that reduces the Residual Risk to an acceptable level.

11.1.3 Close / decommission. In this alternative the Forest Service would close and decommission the Cook Lake Recreation Area, drain the lake, and breach the dam, or portions of each. This alternative results in large up-front expenses, yet results over the long term, in significant savings in maintenance and operations. Should this alternative be selected the recommendations that follow would not pertain.

11.2 Continue Monitoring

11.2.1 Landslide Monitoring. Several monitoring sources exist which presently aid the Forest Service with decision making on whether to evacuate and close the Cook Lake Recreation Area. (Emergency Action Plan: Cook Lake Dam, 2014.) The Forest Service installed and surveyed 17 monuments in the slide and slide-area in 2014 to

assist with detecting earth movement and, to a degree, the rate of any movement. Surveying the monuments on-site is an intensive time consuming activity requiring the better part of two days for two people. The Forest Service will complete a resurvey of these 17 monuments and analyze the data from the results of this survey prior to making a decision on how to proceed with the Management options listed above.

11.2.2 Precipitation Monitoring. The Bear Lodge Remote Automatic Weather Station (RAWS) is about 1 mile south of the Cook Lake Recreation Area. The RAWS allows people to access current information on precipitation and its trends (http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?wyWBEA). The National Oceanic and Atmospheric Administration's (NOAA) Climate Reference Network (CRN) has a remote weather station near the recreation area at Massengale Flats in the Bear Lodge Mountains (https://www.ncdc.noaa.gov/crn/station.htm?stationId=1487). This station is near the top of the Beaver Creek Drainage, 5.3 miles south southwest of the slide. This CRN allows the Forest Service to know whether a single or a group of precipitation events approaches or exceeds a targeted threshold, such as the receipt of more than 3.5 inches of precipitation in 30 days (15%+ of annual total precipitation and more than 200% of the normal 30 day average) (see appendix B). The assessment team cannot overstate the importance of these two remote weather reporting sites for they provide somewhat redundant reporting in the case that one station is off the air; and they are upstream of the dam. The remote weather reporting station at the Albert Pike Recreation Area in Arkansas was miles downstream of the campground. (Recreation Visitor Safety Report, 2010; Review Team Report, 2010.)

11.2.3 Seismic Monitoring. Seismic activity may also contribute to the initiation of landslides. Forest personnel access the United States Geological Service's (USGS) Advanced National Seismic System's, IU-RSSD site http://earthquake.usgs.gov/monitoring/operations/station.php?network=IU&station=RSSD#availability for Black Hills-area seismic trends, recent, and current activity. This station is also useful for providing baseline information since seismic events are not forecasted and sporadic.

11.2.4 Physical Presence. Forest line officers may situationally also post personnel to monitor the water level of Cook Lake, water flow through the spillway and its level – when receiving above average rainfall. The Authorized Officer may evacuate visitors from the lake's west side - and barricade the access to the lake's west side facilities in the event of high water levels in the spillway, or other conditions raising concerns for human safety. (Emergency Action Plan: Cook Lake Dam, 2014; Recreation Visitor Safety Report, 2010.).

11.2.5 Long Term Monitoring Plan. The Risk Assessment Team recommends a long-term monitoring plan including: real-time slide movement, precipitation, soil saturation levels, and lake water-level. In addition, it is critical to have the presence of a trained campground host or personnel on site with adequate and redundant communications – when precipitation and / or soil saturation are above normal or during and in anticipation of large precipitation forecasts.

11.3 Update emergency action plan (EAP). The Risk Assessment Team recommends updating the Cook Lake Dam Emergency Action Plan with the involvement of Crook County

Emergency Management. The update should include the present landslide monitoring measures, trigger points, management actions, and further updates as new monitoring measures are brought on line. (Emergency Action Plan: Cook Lake Dam, 2014; Recreation Visitor Safety Report, 2010; Review Team Report 2010.)

11.4 Gates, fencing, signing, post safety zones. The Risk Assessment Team recommends installing warning signs to inform the visitors of danger, fencing at the closed area near the toe of the slide, and around lakeside areas of the slide itself to keep the public out of the danger zone. The Forest Service should brief employees and volunteers on potential safety zones for high water or probable dam failure in the case that an evacuation is not completed prior to imminent threat.

11.5 Communication to recreation area. On-site personnel are necessary during the open season. Presently the Forest Service provides a Campground Host with a Forest Service radio. The Risk Assessment Team recommends that the Forest Service provide a satellite telephone to the Campground Host in addition to the Forest Service radio to provide a redundant communication means to ensure that emergency communications are available. Presently there is no cellular telephone signal available in the valley at the Recreation Area. The Forest Service should consider the feasibility of establishing a remote repeater to serve the area or the possibility of using satellite telephone during the recreation season. (Recreation Visitor Safety Report, 2010; Review Team Report, 2010.)

11.6 Install additional monitoring (water level, inclinometers, piezometers, time- delayed reflectometry). The use of new monitors with telemetry will allow for real time monitoring and data access, as well as the ability to provide warnings when set at predetermined thresholds. The warning thresholds will be set and updated in the updated Emergency Action Plan based on accumulated baseline data. (Cook Lake Landslide Stability Analysis, 2016)

> 11.6.1 Lake Level. The Forest Service is calibrating a pressure transducer to monitor water levels of the lake. This monitor will send out a 911-alarm via satellite phone when the Lake's water level at the spillway rises to the 10%, 50%, and 100% levels of spillway capacity. This monitoring system will be operational in June of 2016. The telemetry for the water level monitors allows remote monitoring. (Personal communication with Region 2 & 3 Dam Engineer; and see generally, Review Team Report, 2010 and Recreation Visitor Safety Report, 2010.)
>
> 11.6.2 Landslide Monitoring. The Risk Assessment Team recommends purchasing and installing a series of inclinometers, piezometers, time-delayed reflectometers to use telemetry to monitor conditions in the landslide area. (Cook Lake Landslide Stability Analysis, 2016.) The inclinometers and piezometers monitor the rate of tilt and internal water pressure of the landslide, respectively. The inclinometers give information on the rate and directions of earth movement, whereas the piezometers monitor soil saturation. The time-delayed reflectometers are a series of inexpensive cables buried at known points across potential fault or stress points, which break in response to earth movement. The break can trigger an electronic signal via telemetry to the data collection point, yielding information on recent sudden earth movement, which can be a sign of impending larger scale slope failure. This data can be used to issue an automated electronic warning to the campground host, Forest Service, and Crook County emergency response personnel. (See generally, Review Team Report, 2010 and Recreation Visitor Safety Report, 2010.)

11.7 Improve emergency exit U-road 620052 and re-routing or acquiring an easement on a segment. The Risk Assessment Team recommends minimally improving the emergency exit road through the supply site off of the access to Loop B. In an emergency event the road would be ready for opening with less effort. This may include re-routing a 200 feet segment to Forest Service land from private land or acquiring an easement on the private road segment, if necessary. The forest then could establish this route as part of plan for emergency evacuation of the recreation area. (Recreation Visitor Safety Report, 2010.)

11.8 Interpretation and public education. The Risk Assessment Team recommends using interpretation to inform the public of the geologic risk associated with recreating in the area and the best ways to stay safe. Interpretation should include signs in the recreation area describing the landslide. The Forest Service should continue its public education of the danger at Cook Lake through news releases, public meetings, and personal communication. (Recreation Visitor Safety Report, 2010; Review Team Report, 2010.).

11.9 LIDAR Survey Data. The Risk Assessment Team recommends obtaining LIDAR survey data for the Cook Lake Landslide. The use of light detection and ranging (LIDAR) surveying technology is presently unavailable to the Black Hills National Forest. The use of LIDAR technology could detect crown fractures, the forming of basins, and the loading of slopes that are otherwise invisible to the naked eye. Having LIDAR data available would facilitate the Cook Lake risk assessment and continued monitoring. Its availability would improve recommendations and would greatly contribute to defining the screening level risk matrix and trigger points used in the Emergency Action Plan.

11.10 Management. The Risk Assessment Team recommends that it is in the best interest of the public to not open and then re-close the Cook Lake Recreation Area. It would be preferable to continue the closure order in effect, as opposed to opening then re-closing. An interim opening is supportable when the decision path forward is clear, that funding is available, and mitigation measures are in the process of implementation.

11.11 Interim Use. Until new monitors and mitigations described in this document are in place and working, interim use of the Cook Lake Recreation Area may be acceptable due to the low winter and spring precipitation in 2016 and the resulting drier soil conditions. If interim use is desired, the Risk Assessment Team recommends the following:

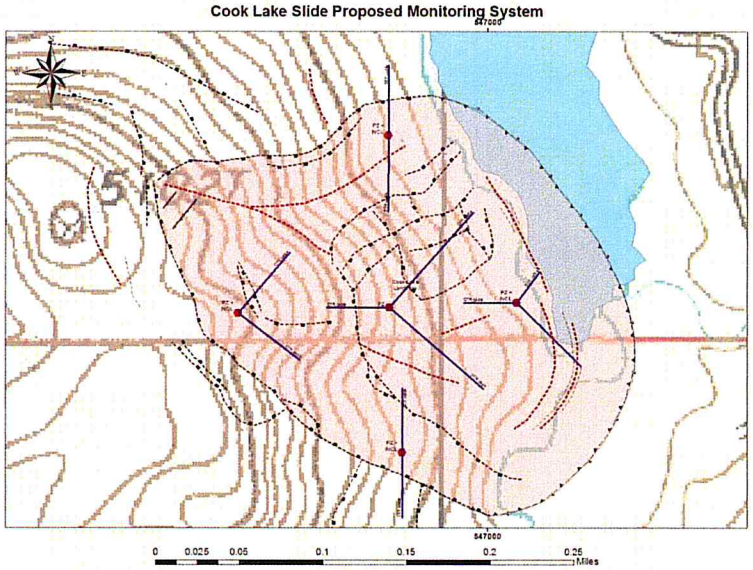
- A Forest Closure Order for the area of the slide on the southwest side of the lake most likely to be impacted by earth movement, posted with signs depicting the closed area;
- On-site personnel (campground host) trained and with communication;
- Lake water-level monitoring installed and working;
- A resurvey of the 17 monument slide monitoring points to establish no appreciable change from the baseline;
- An Emergency Action Plan under revision that also assigns monitoring duties to employees and defines interim trigger points and actions;

Appendix A. Cook Lake Landslide Monitoring Program

The Colorado School of Mines completed a geotechnical investigation (Stability Analysis) on the Cook Lake landslide. The Stability Analysis recommended the installation of a monitoring network to insure that future movements on the slide zone are assessed in real time. Thus, management information to make decisions over safety issues have the time to mitigate any increased risks to the public and area facilities. These recommendations include:

- monitoring of surface survey monuments to track slope movement in real time;
- drilling and installation of piezometers and inclinometers to measure water levels and identify the slope failure surface, respectively; and
- Testing of the sensitivity of the Redwater Member, as well as strength testing of samples from the slide plane.

The Colorado School of Mines suggested the emplacement of 3 to 5 subsurface inclinometers and piezometers in the following general arrangement. These devices would be emplaced in 250-400 ft. deep test holes, connected to data-loggers that are satellite linked to provide real time monitoring of the slide's movements.



The bore holes in which these devices would be emplaced will also provide the opportunity to sample the Redwater Member and slide-plane lithologies to better define the landslide's geotechnical characteristics. Also shown in blue on the above diagram area series of TDR (Time Delay Reflectometry) cables emplaced in shallow channels along the surface, which serve to warn against sudden movements that exceed the elasticity limits of the cable. These cables are attached to a TDR pulse generator and reader that determines the positions of any breaks and kinks in line, and uploads that information to the multichannel data-logger at the nearest inclinometer-piezometer emplacement. These cables are inexpensive and easy to install, consisting of little more than a standard RG-6 Coaxial cable.

The overall costs associated with establishment of the entire monitoring network, including will be in the range of $65K-$110K, based on a recent canvassing of suppliers and geotechnical drillers.

Appendix B. Bear Lodge RAWS Precipitation Data

Bear Lodge Raws Precipitation Data (1985 - 2016)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1985	0.00	0.17	0.78	1.08	2.29	2.91	1.10	0.48	1.81	0.69	0.34	0.83	12.48
1986	0.34	0.30	0.65	3.25	2.41	3.86	2.37	0.79	4.21	1.92	0.38	0.04	20.52
1987	0.21	0.62	1.04	0.43	NA	NA	NA	NA	NA	NA	NA	NA	NA
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.24	NA	NA
1989	NA	0.00	0.06	2.12	2.83	3.36	1.87	0.74	1.73	0.97	0.72	0.56	14.96
1990	0.13	0.04	0.41	1.44	3.15	0.76	2.24	1.40	0.27	0.90	0.26	0.00	11.00
1991	0.03	0.41	0.23	1.91	4.81	1.84	1.31	0.79	0.77	0.27	0.16	0.37	12.90
1992	0.02	0.32	0.91	1.92	1.98	2.74	4.13	1.10	0.78	0.80	0.80	0.08	15.58
1993	0.15	0.07	0.69	2.28	2.51	9.25	3.95	2.08	1.26	0.63	0.27	0.20	23.34
1994	0.54	0.29	0.18	1.51	2.15	1.59	2.67	0.55	1.52	6.71	0.39	0.17	18.27
1995	0.09	0.23	1.19	1.08	9.44	3.85	3.10	1.37	0.71	3.87	1.21	0.19	26.33
1996	0.40	0.17	1.59	1.99	3.93	0.78	1.26	1.97	1.00	1.71	0.43	0.70	15.93
1997	0.08	0.44	0.65	1.33	2.59	3.55	3.76	1.29	1.36	1.27	0.72	0.41	17.45
1998	0.48	0.36	0.81	1.14	0.87	4.96	3.46	4.65	1.31	6.65	0.36	0.10	25.15
1999	0.79	0.29	0.64	2.73	3.20	5.33	2.49	2.16	1.30	0.40	0.63	0.40	20.36
2000	0.16	0.34	1.46	2.82	2.79	3.80	1.01	0.38	1.24	1.56	0.59	0.21	16.36
2001	0.02	0.29	0.95	2.12	0.91	4.70	3.97	0.15	0.55	1.31	0.17	0.01	15.15
2002	0.04	0.47	0.71	1.50	1.77	0.89	0.50	5.78	2.85	0.58	0.53	0.16	15.78
2003	0.90	0.74	1.10	2.05	2.57	5.13	1.24	0.48	3.74	0.46	0.30	0.11	18.82
2004	0.34	0.26	5.45	1.96	2.20	0.82	3.58	1.68	1.13	1.94	0.73	0.04	20.13
2005	0.13	0.15	0.69	2.68	5.60	3.45	1.73	0.91	0.58	1.87	0.54	0.82	19.15
2006	0.20	0.48	0.73	2.92	4.87	1.13	0.45	1.66	6.18	1.33	0.23	0.04	20.22
2007	0.18	0.70	1.34	1.34	8.87	3.17	1.69	3.18	0.73	1.28	0.20	0.38	23.06
2008	0.16	0.63	0.65	1.44	3.37	6.39	2.75	2.67	2.05	0.99	0.84	0.52	22.46
2009	0.70	0.26	1.35	2.86	1.55	4.78	3.33	2.41	0.69	2.46	0.13	NA	20.52
2010	NA	0.33	1.11	2.85	5.45	3.40	2.16	1.95	1.26	NA	0.44	0.41	19.36
2011	1.13	0.34	1.30	1.84	6.99	1.90	1.74	1.60	1.00	1.25	0.58	0.70	20.37
2012	0.99	1.18	0.32	2.37	2.27	0.53	2.13	2.91	0.05	1.44	0.39	0.47	15.05
2013	0.25	1.22	0.79	1.96	9.72	2.96	2.33	2.46	2.25	3.57	0.46	0.60	28.57
2014	1.77	0.65	1.51	2.64	1.75	5.54	0.98	1.12	2.11	1.14	0.95	0.65	20.81
2015	0.48	0.65	0.97	1.72	6.13	3.10	1.32	2.20	0.58	2.28	0.32	0.64	20.39
2016	0.90	1.23	1.80	2.60	0.58	0.48							7.59
Mon. Av.	0.39	0.45	1.07	2.06	3.78	3.34	2.23	1.76	1.55	1.73	0.49	0.34	

Average 29 out of 31 years of Data		19.24 in	Significant Precipitation Months (>5.0 in)
			Years w/ Above Average Precipitation
Low year	1990	11.00 in	Years w/ 117% to 135% of normal Precipitation
High Year	2013	28.57 in	Years w/ 135% to 150% of Normal Precipitation

1 standard deviation =	3.45				"Normal" = 15.79 to 22.69
1 standard deviations above normal =	22.69	1 stand.dev. below normal =	15.79	"Abnormally" wet =	>22.69
2 standard deviations above normal =	26.14	2 stand.dev. below normal =	12.34	"Abnormally" dry =	<15.79

1. The normal range of precipitation is considered to be plus or minus (+/-) one standard deviation from the average yearly value. In the Bearlodge RAWS data for the last 28 years, this means about **3 ½ inches** above or below the average of **19 ¼ inches** of precipitation. This "normal" range of values is predictably found in approximately 2/3 of the data years, with the remaining 1/3 of the years representing "abnormally" dry and wet conditions.
2. Plus or minus 2 standard deviations typically includes more than 96% of the expected range for the data so anything outside those high and low values is significantly unusual. Only two values in the data are outside of this range; 1995 and **2013** were both record highs up to that point in time. The last major slide occurred about two years after the 1995 event, and 2013 appears to have set us up for a similar event in the near future.
3. A significant short term event is considered to be approximately **3 ½ inches**, as events of that magnitude have historically caused near overflows on the dam spillway. This value is about plus 1 standard deviation, and over 200% or the average monthly precipitation.
4. A significant monthly event appears to about **5 inches**, which represents about 135-150% of the average for the highest precipitation months of May and June. Almost all of the significant monthly totals shown on the chart include a short term even at or exceeding a plus one standard deviation event (**3 ½ in**)
5. We currently do not have an established baseline for Soil moisture, (subsurface pore pressures) but these values will directly reflect precipitation totals over an extended period of years. Monitoring by piezometers will provide that correlation once installed.

Appendix C. Emergency Action Plan

For the Emergency Action Plan, Cook Lake Dam, revision date May 15, 2014, see:
O:\NFS\BlackHills\Program\7500 WaterStorage&Transmission\Engineering\7570DamMgmtSystem\Dams\Cook_Lake_dam_1003\Cook-dam-eap.pdf

Appendix D, Impacts and Consequences

Impacts and Consequences

Risk to lives and property

Visitor safety is a fundamental aspect of a quality outdoor recreation program. Given the importance of recreation to local economies, public health, and quality of life, visitor safety received a national evaluation from the Forest Service via the Recreation Visitor Safety Report, 2010. The Landslide Stability Analysis shows an existing risk to forest visitors on Cook Lake's west side. The consequence is that the Forest Service could consider closing facilities and access to the west side and using a Forest Closure Order to protect the public. (Cook Lake Landslide Stability Analysis, 2016.)

Loss of recreation opportunity

The temporary or long-term closure of Cook Lake will result in the loss of a significant recreation resource for the Black Hills National Forest, the Bearlodge Ranger District, and Forest visitors – however public safety is a fundamental aspect the Forest Service's recreation program.

Loss of Infrastructure: dam, campground, road

There is significant investment in the recreation infrastructure at the Cook Lake Recreation Area. Decommissioning costs of the removal of the infrastructure will be expensive and have significant impact on the forest budget requiring other projects to go under or unfunded.

Increase deferred maintenance

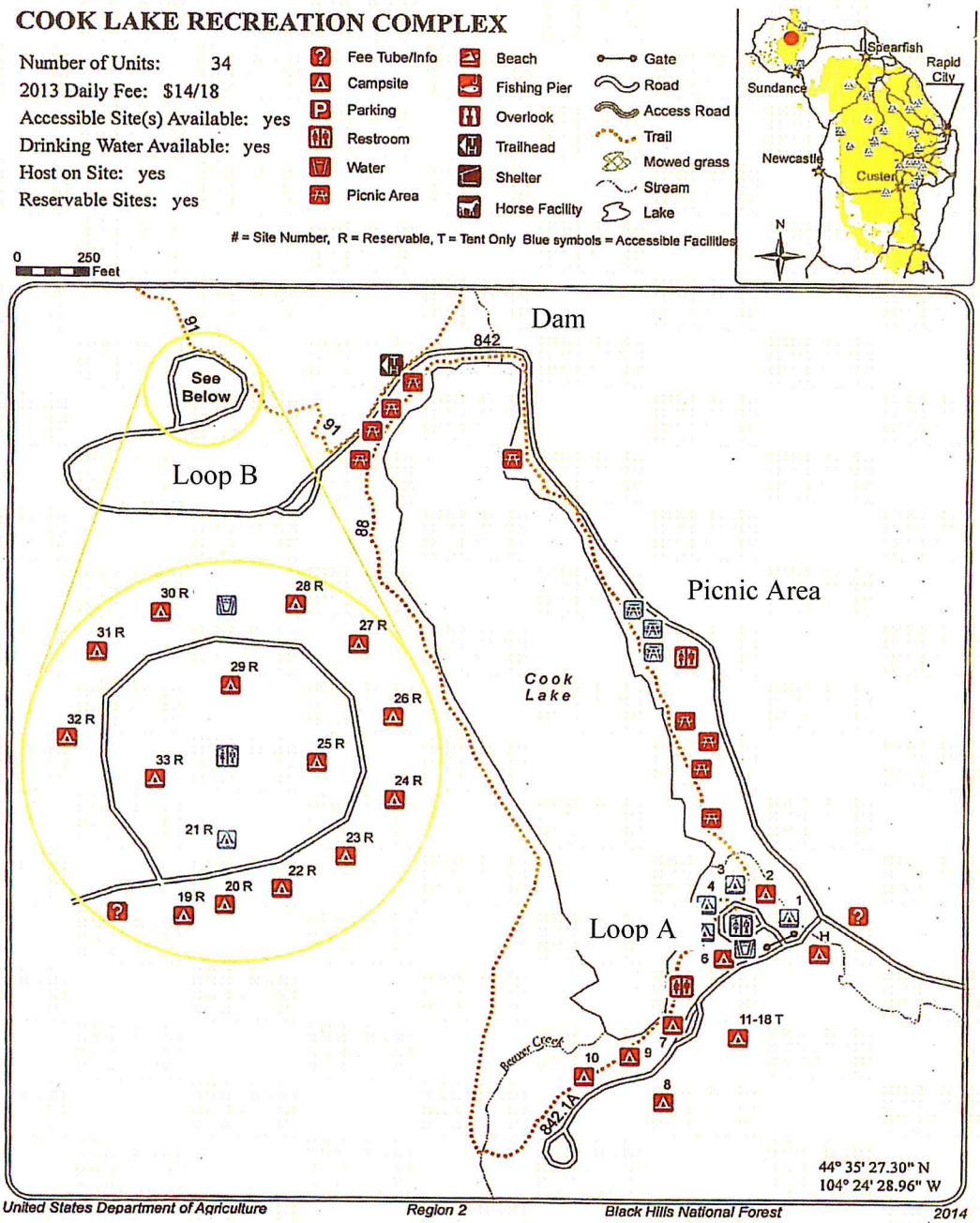
The Cook Lake Recreation Area closure added to the deferred maintenance costs of the facility. Continuance of the closure would increase deferred maintenance further. The Forest Service manages the recreation area through a concession permit. Visitor fees collected there stay on site for the area's maintenance and improvements. No revenue has been collected or made available to help with maintenance of the area due to the closure.

Funding for mitigation, installation of new monitoring, and future cost

Capital Investment Program (CIP) funds in the amount of $1.3 million have been allocated for the Cook Lake Dam improvement. Recommend that a portion of these funds (about 5 to 8.5%) be used for establishing the suggested mitigation measures for safety. The remainder of the funds would be available for repair or rehabilitation of the dam and / or spillway.

Appendix E. Schematic of Cook Lake Recreation Area

Extract from the Prospectus for Campground and Granger-Thye Concessions, Black Hills National Forest.



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