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RESEARCH SUMMARY

Experience has shown that road networks needed for conventional logging can lead to severe erosion in the Idaho Batholith. In an attempt to develop an environmentally acceptable logging system, in 1971 the Forest Service, USDA, in cooperation with Boise Cascade Corporation, began an experiment with balloon logging in Anderson Creek near Garden Valley, Idaho, on the Boise National Forest.

The balloon logging system resulted in far less environmental impact on the land as compared to conventional logging methods. This conclusion is based on observations both shortly after the area was logged and after several years had passed.

This sale proved the physical capabilities of logging with the balloon system in the Idaho Batholith area; however, the conditions are not ideal, with the steep, broken terrain and low timber volumes. A description of the equipment, the methods of operation, and problems with the system are included in the report.

An economic analysis of the logging is presented in the form of regression equations. Factors within the analysis include thousand board feet logged per acre, board feet per piece, pieces per productive hour, turns per productive hour, percent productive hours, and costs per thousand board feet.

INTRODUCTION

The Idaho Batholith comprises 16,000 mi^2 (41,440 km^2) of steep, highly erodible terrain in central Idaho. Because experience has shown that roadbuilding in the Batholith can cause accelerated erosion rates and lead to mass instability problems, many stands of overmature ponderosa pine and Douglas-fir have not been harvested.

In an attempt to develop an environmentally acceptable logging system, in 1971 the Forest Service, USDA, in cooperation with Boise Cascade Corporation began an experiment with balloon logging in Anderson Creek near Garden Valley, Idaho, on the Boise National Forest. The selection of this system was based on projections (McIntosh 1968) of balloon yarding costs from tests conducted in British Columbia and reports from Bohemia Lumber Company's balloon logging operation in Deception Creek, Oregon, where an onion-shaped balloon proved successful.

Major objectives of this study are to evaluate environmental impacts, logging capability, and economic feasibility of balloon logging in the Rocky Mountain area. Gardner and others (1973) reported that this balloon logging experiment appeared to be environmentally acceptable based on short-term observations, was physically capable of logging the area within the restraints caused by terrain, and was marginal from an economic standpoint for logging in the Idaho Batholith.

The purpose of this summary report is to present a detailed analysis of the balloon logging costs, production data, and to evaluate the environmental effects of balloon logging after several years' observation. During August 1977 the balloon sale area was revisited in order to make a visual inspection of the environmental impacts as they appeared several years after the logging was completed. Photos were taken of the area and these showed that visual effects of the logging disappear rapidly where ground disturbance was minimized. This inspection covered roads, cut areas, landings, and streams.

ENVIRONMENTAL IMPACTS

The balloon logging system proved to be an effective logging tool from an environmental viewpoint. The 3,000 ft (914 m) maximum yarding reach with this system allowed the area to be logged from existing roads. This resulted in far less damage to the logged area (Anderson Creek watershed), as compared to logging done in previous years with cat-and-jammer logging systems and the associated dense network of roads. The scars from the old logging and roads are still readily apparent, even though it has been over 20 years since much of the logging took place. Figure 1 shows an extreme example in the northern part of the Idaho Batholith of how an area looks when closely spaced roads are required to facilitate the logging method. In contrast, figure 2 shows an example of the appearance of an area shortly after being logged with the

Figure 1.--An extreme example of closely spaced roads to facilitate the logging system in the Northern Batholith.

Figure 2.--An area logged with the balloon logging system.

Figure 3.--Photo 5 years after the timber was removed shows very little evidence of logging.

balloon system. The esthetic advantages of balloon logging are readily apparent from the air or on the ground as there are few scars left on the landscape compared to the conventional logging methods. This visual observation has proven true at this site soon after logging and after several years have passed since the logging took place (fig. 3).

Lifting logs vertically with the balloon and flying them to the landing allows any cutting method to be used. On this sale, an overstory removal harvesting method was used with a minimum diameter specified, in order to release the understory. Minimum diameter varied depending on the unit, but most units had a 13-inch (33-cm) minimum diameter. Very little damage to the understory resulted, and the majority of this damage occurred during the felling operation. A few limbs were broken by the main and haulback lines and flying logs, but this damage was minimal.

A buffer strip of timber was left uncut, adjacent to stream channels in each logging unit. This was an effective method of protecting the stream, and the only apparent damage was due to a few logs being accidentally dropped into the creek during the yarding operation. Any debris from the logging was removed and the creek shows no effects from the logging. Figure 4 shows a typical reach of Anderson Creek as it was in August 1977.

Landing construction was a source of ground disturbance. In order to minimize this disturbance, many of the landing areas were less than one-half acre (0.2 ha) in size, or the road surface was used for a landing area (fig. 5). A bedding area (fig. 6) was constructed in the Cow Creek subdrainage for tying the balloon down during severe storms or for maintenance work on the balloon. This was the only sizable embankment constructed for the balloon logging operation, and some erosion resulted--the majority being during a high intensity rainfall shortly after construction. The gullies from the erosion have been vegetated and have stabilized as shown in figure 7.

Figure 4.--In August of 1977, Anderson Creek shows little signs of logging.

Figure 5.--Small landing areas adjacent to or on the road minimized the amount of ground disturbance.

Figure 6.--Balloon bedding area in the Cow Creek subdrainage as it appeared shortly after construction.

Figure 7.--Photo taken 6 years after bedding area was built shows that gullies have been stabilized and the fill banks are vegetated.

The reduction in the density of roads with the balloon system leaves the land man-
ager with limited access to manage the land. This can be a problem especially where
fire, disease, or insects are a threat because proper slash treatment is difficult due
to poor access. This is not to say that proper slash treatment cannot be accomplished,
but that the high costs of treatment must be considered as an extra cost in the balloon
system as compared to logging systems using a more dense road network. Regeneration
and other management functions also will be more difficult and expensive because of the
limited access provided by the balloon logging road system.

PHYSICAL CHARACTERISTICS
AND LOGGING CAPABILITIES

This sale proved the physical feasibility of logging with a balloon system in the
Idaho Batholith area; however, the conditions are not ideal. Steep slopes, generally
45 to 90 percent, made working conditions difficult for the riggers, fellers, and
choker setters. The highly dissected drainages made frequent cable road and layout
changes necessary in order to reach the logs. Figure 8 shows the severity of the
terrain on a contour map of the logged area.

The main piece of equipment for the half-million-dollar (1971 cost) yarding system
was an onion-shaped, Dacron-neoprene fabric balloon which is 113 ft (34.4 m) in height
and 105 ft (32 m) in diameter. The 560,000 ft^3 (15,857 m^3) helium-filled balloon had
a net lift of 22,500 lb (10,206 kg) shortly after inflation. This lift varies consid-
erably with elevation and temperature. (Temperatures in the Garden Valley area of Idaho
range from below zero (-17.8° C) to above 100° F (37.8° C)). On cold mornings when the
temperature was below freezing, decreased lifting capacity slowed the yarding operation
considerably. The lifting capacity of the balloon is also greatly reduced by even a
thin covering of snow or ice. A heavy snow can cause the balloon to tear due to the
snow load or from the rebound when a snow load slides from the balloon. A tear did
result from a sliding snow load and the resulting quick load release. The snow condi-
tions at the logging site required that the balloon be stored for 3 or 4 months during
each winter. Storage is a problem, as there is no economical way to deflate the
balloon and store the gas. Snow removal was a continual maintenance burden for the
logging company during winter bedding of the balloon (fig. 9), but it was the most
economical solution since enough helium to fill the balloon cost approximately $25,000.

A very small amount of leakage occurred during normal operations, but this was not
a problem and was within the expected loss estimates. The balloon's reflective aluminum
surface was repainted during the 3-year sale in order to prevent excessive weathering of
the fabric and to control temperatures caused by radiation from the sun.

Wind affects yarding in proportion to velocity, with the operation being consider-
ably slower as the limiting operable velocity of approximately 25 mi/h (40 km/h) is
approached. Variable winds are also troublesome even at low wind velocities due to the
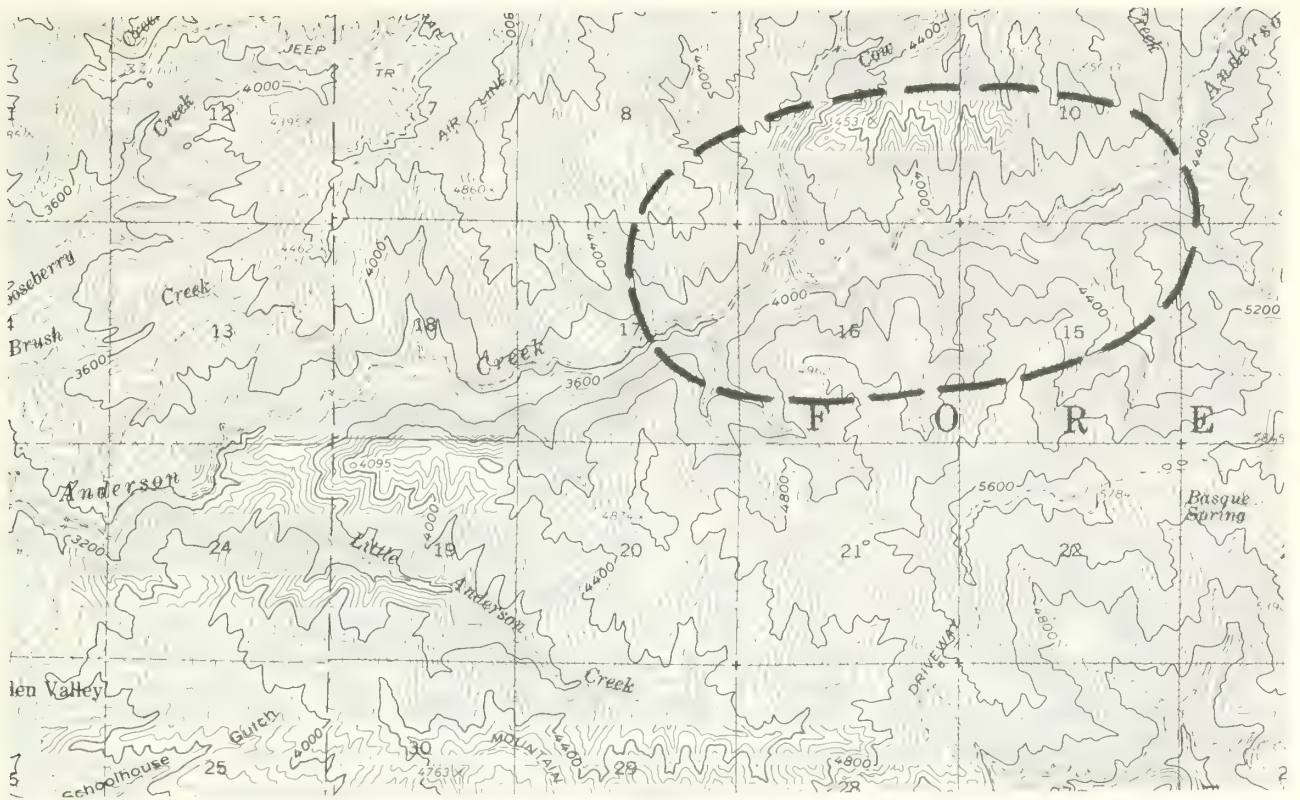problems with landing loads and positioning over the logs for hooking chokers.

Figure 8.--Contour map of the balloon logging area in the Idaho Batholith shows the steep and broken terrain. (Study area within dotted line.)

Figure 9.--Balloon winter bedding area near Garden Valley.

Figure 10.--Washington Model 608A yarder.

The yarder (fig. 10) was built by Washington Iron Works for the balloon logging system. Aero Yarder, Model 608A, has hydraulic interlocking drums with a mainline capacity of 5,500 ft (1,676 m) and haulback capacity of 7,000 ft (2,134 m) with 1-inch (2.54-cm) cable. The weight of the yarder is approximately 160,000 lb (72,575 kg) with a tracked undercarriage. Hydraulic problems and planetary gear problems occurred during the first year's operation, but the newly designed yarder performed satisfactorily during most of the last two logging seasons. An HD-21 tractor equipped with a large capacity hydraulic winch was used for transporting the balloon. The balloon was tethered to this tractor during maintenance and moving operations.

A schematic of a typical yarding layout for the sale is shown in figure 11. The figure illustrates the continuous cable system with the balloon providing a lifting force to fly logs from the stump to the landing. Location of the 5/16-inch (0.79-cm) strawline used for restringing the mainline is also shown. Figure 12 shows the operations schematic for a typical yarding turn.

The yarding turn starts with the balloon leaving the landing area unloaded. The balloon's buoyant force provides a portion of the power to move the system out to the felled logs. When the balloon is over the logs, tension is applied to the mainline and haulback to pull the balloon down so the tagline can be reached by the choker setters (fig. 12A). The chokers have been preset on the load of logs so that the load can be quickly hooked to the tagline and the men can move clear of the area. The choker setters then radio the machine operator that the load is hooked and ready to yard. The lines are slacked so the balloon rises nearly vertically to clear the understory and the yarder begins pulling in the mainline while simultaneously slacking the haulback (fig. 12B). As the logs approach the landing area, the rate of travel is slowed to minimize swinging of the load and the lines are tensioned in order to set the logs on the landing area (fig. 12C). The chokers are unhooked from the logs and flown back to the choker setter as the cycle starts again.

The steep slopes and narrow drainage bottoms limited the size and location of landing areas. Availability of landings is an important factor when laying out the sale units; thus, the landings dictated much of the sale layout. Fortunately, the balloon system layout is not further limited by cable deflection requirements, the only requirement being that the main and haulback lines do not rub the ground. Small landing size is a safety problem because the log deck can quickly become a jackstrawed maze of logs when the loader used for clearing the log landing area is temporarily out of service. This makes the unhooker's job especially dangerous during the unhooking operation because of the possibility of shifting logs. In general, safety is decreased when the landings are small because of the increased congestion of men and equipment. Production is slowed with small landings since the swinging load of logs has to be brought into the landing more slowly for adequate control in setting the logs down on a small area.

The tagline, to which the chokers are attached, was varied in length as the terrain dictated. The longer length tagline allows the chokers to reach the ground with less effort expended in pulling the balloon down. However, the longer tagline caused the chokers and logs to swing more than a shorter tagline, thus taking more time to position the chokers for hooking and unhooking. The optimum length for the tagline was judged by the crew depending on wind, terrain, and logging set configuration, and tagline length could vary at each cable road location.

The choker setter's job proved to be difficult for several reasons. The terrain is steep, especially in some of the draws where slopes of 90 percent are encountered. This made dragging the tagline difficult and scrambling from the area below the flight path of the logs strenuous. It is particularly important from a safety standpoint to be clear of the logs to avoid becoming entangled with the load or being hit by a falling log or limb. Summer temperatures (sometimes around 100° F (37.8° C)) and fall snows and rains made the choker setter's job even more arduous.

Yarder operators had to be conscientious and skillful to keep the overall operation safe and efficient. Particular skill and quick thinking are required if a line breaks or a stump pulls loose because the balloon builds up a large inertial force with a few seconds of free flight. The balloon should be slowed gradually with the cable braking system. Locking the brakes on the yarder drums could upset the yarder or snap the cable when the balloon comes to the end of the slack in the cable.

Rigging the balloon system as an inverted standing skyline was tried in order to extend the system reach to over 5,000 ft (1,524 m). This system used the mainline as a standing skyline (nonmoving) and the carriage was inverted on the skyline (lifting the skyline rather than pulling it down) because of the balloon's lifting force. The carriage traveled along the skyline with the balloon pulling it uphill and the haulback line pulling the carriage and the logs downhill to the landing. The method was abandoned after 2 or 3 days because whipping and sawing of the skyline and haulback against each other caused rapid cable wear.
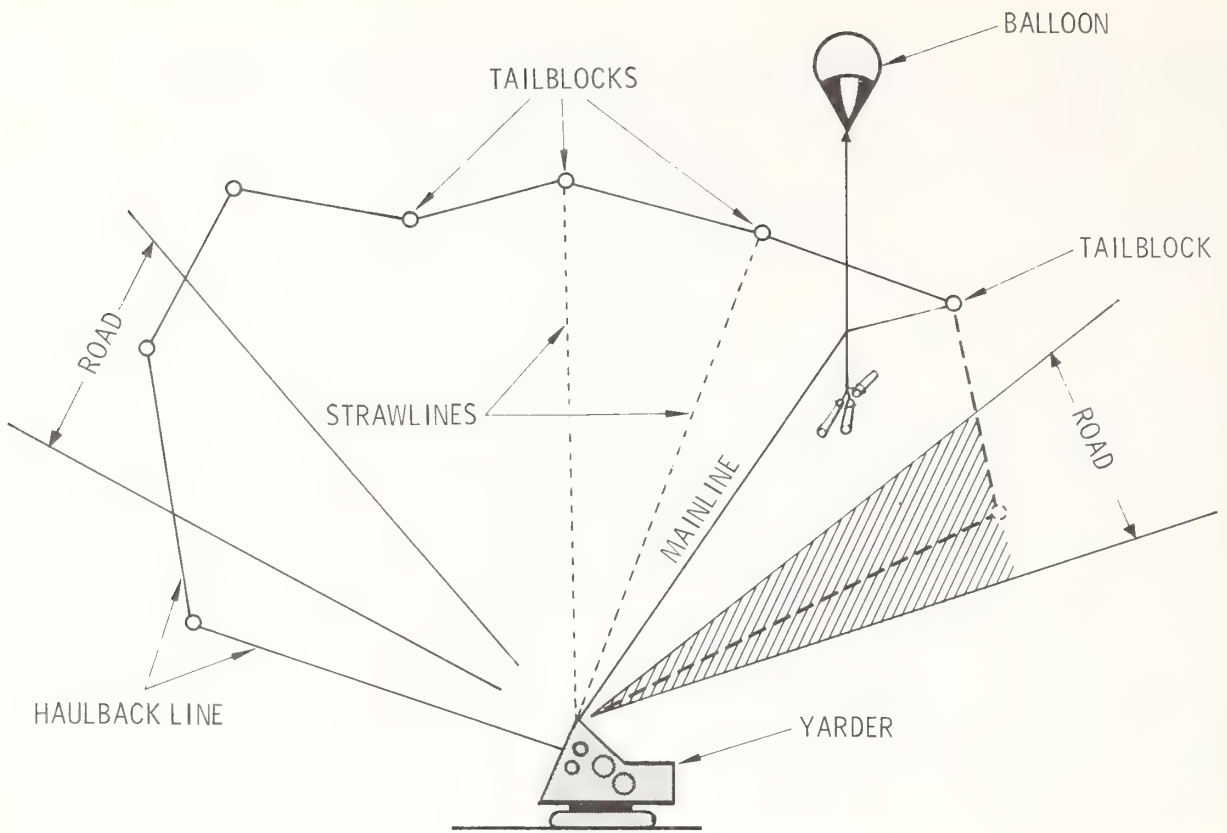
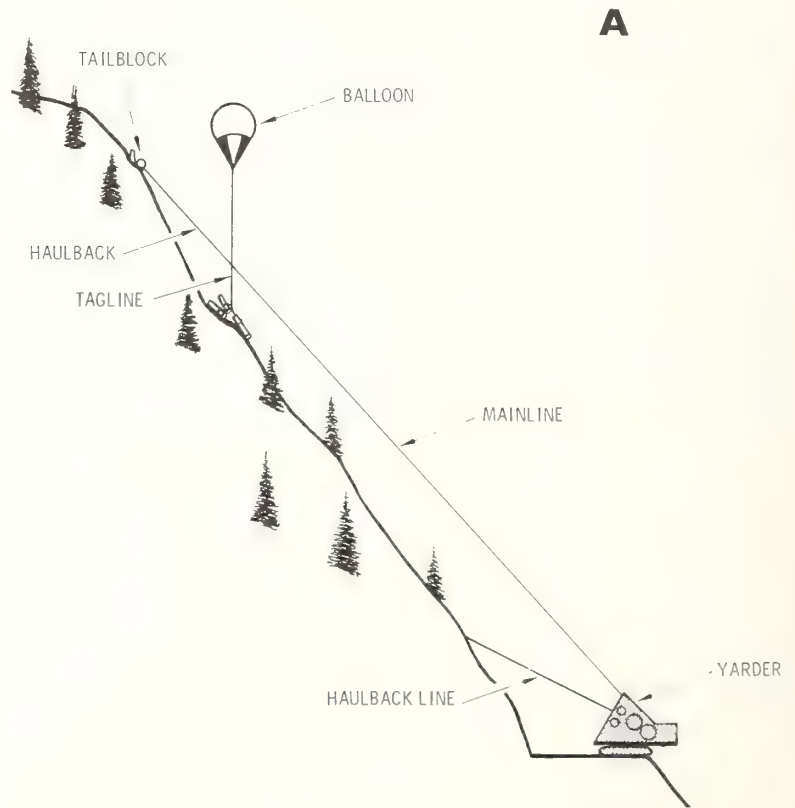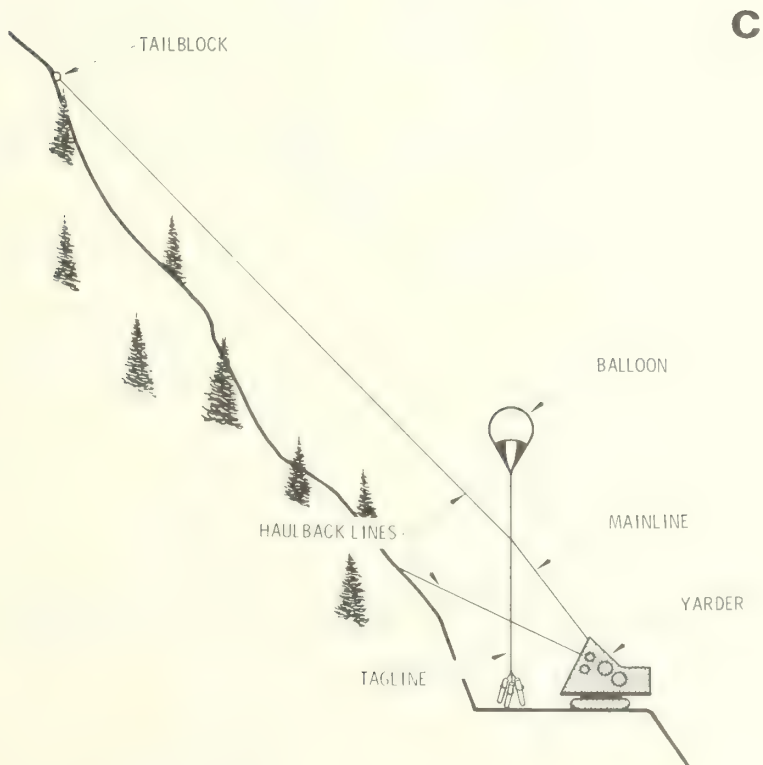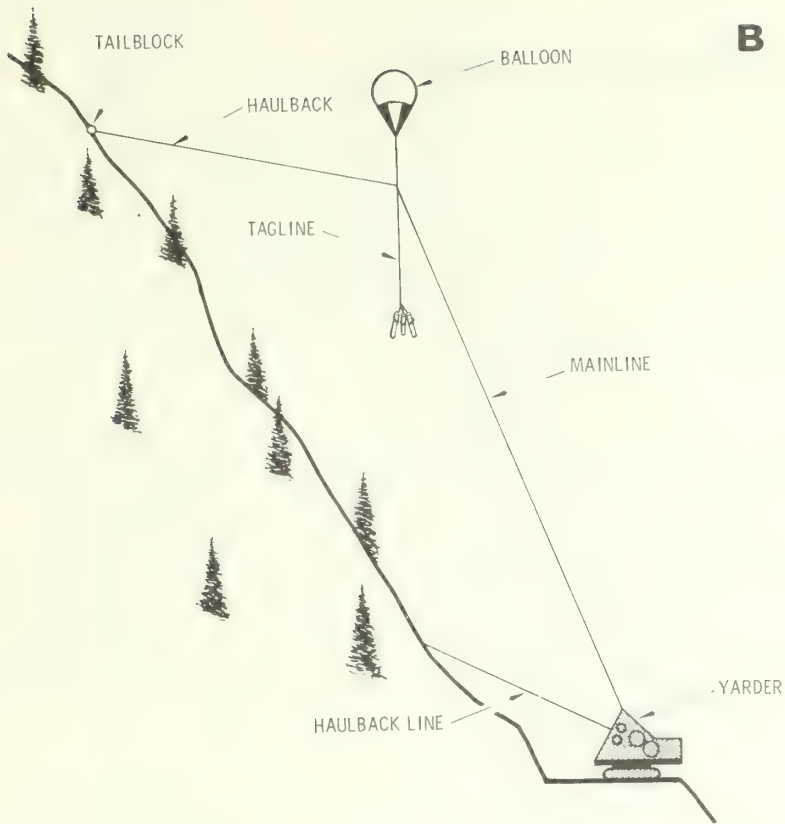*Figure 11.--Typical balloon unit and layout.*

A

Figure 12.--Operations schematic of balloon logging system when the balloon is (A) over the logs, (B) logs are in the air, and (C) logs are at the landing.

B

TAILBLOCK

HAULBACK

BALLOON

TAGLINE

MAINLINE

HAULBACK LINE

YARDER

C

TAILBLOCK

BALLOON

MAINLINE

HAULBACK LINES

YARDER

TAGLINE

11

ECONOMIC FEASIBILITY

The balloon system has proven to be acceptable from an environmental viewpoint and also has demonstrated the physical capability to log in the Idaho Batholith area. The final test for a viable logging system is its economic feasibility. The balloon system's economic feasibility was tested under a specific set of timber stand, harvesting, and terrain conditions in the Idaho Batholith. Unfortunately, balloon logging cannot be compared to conventional logging economics since these methods cannot be used to log terrain similar to the Anderson Creek site due to physical or environmental limitations. It is believed that this economic analysis will prove useful for assessing balloon logging feasibility for the Rocky Mountain area in general.

The first step in the economic analysis was to plot production per hour versus time in days to see if a learning period could be identified during the startup of the system. Cumulative plots of turns per productive hour (fig. 13) and pieces per productive hour (fig. 14) were used because of the high variability in daily production rates. The slopes of the line segments on the graphs indicate that production rates were not time dependent. This is not surprising in view of the circumstances involved on this timber sale. Boise Cascade had sent the crews to another balloon logging job on the West Coast to be trained for the balloon system of logging. Operators were selected that had experience on similar equipment used for cable logging. Supervisory personnel from Bohemia Logging Company (a company with several years of experience with balloon logging) were on hand during the startup and initial shakedown of the system.
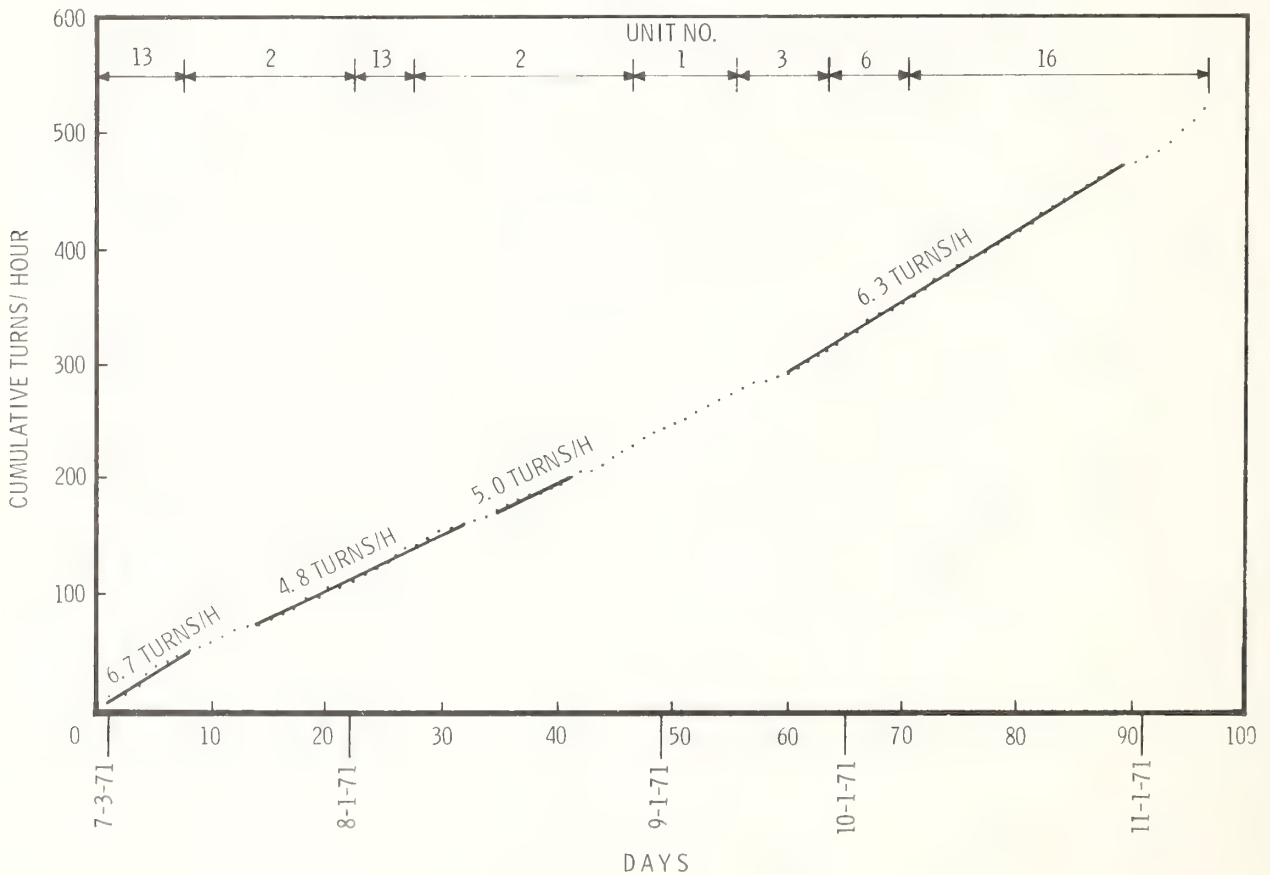

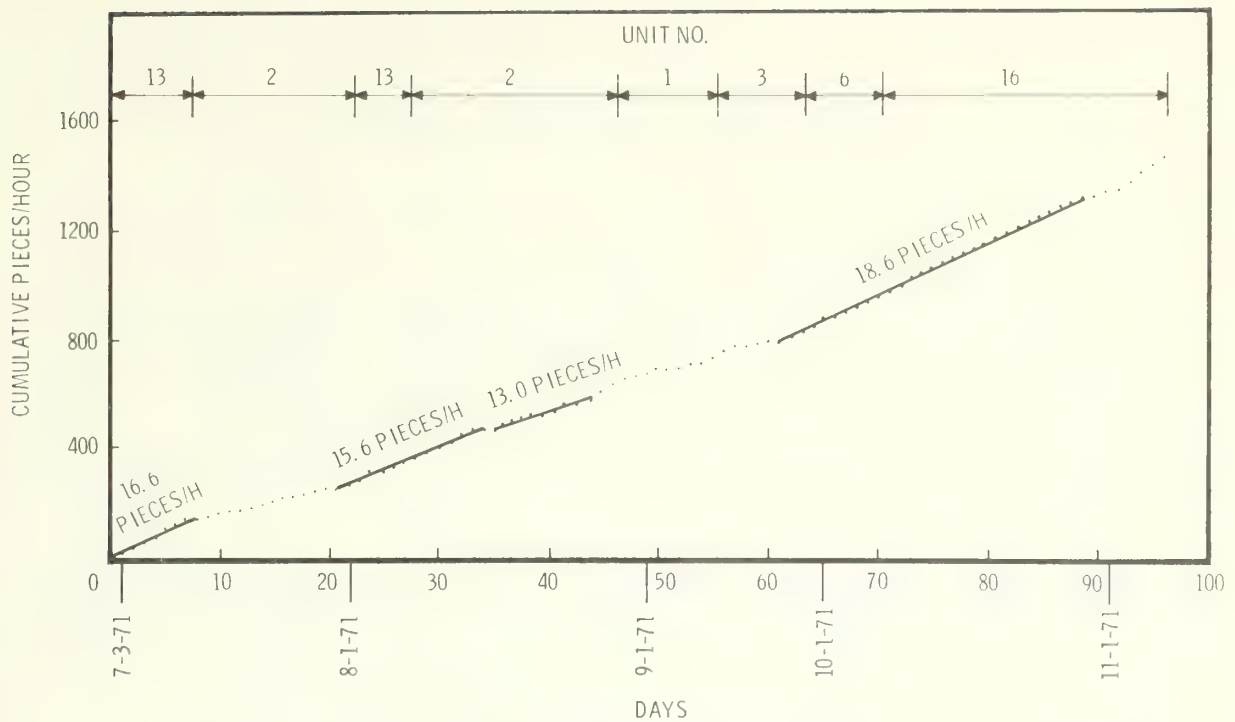Figure 13.--Turns per productive hour (cumulative) vs. date, unit.

Figure 14.--Pieces per productive hour (cumulative) vs. date, unit.

During 1971, gross data were collected on each of the logged units. This informa-
tion included M bd.ft. logged per acre (V), bd.ft. per piece (B), turns per productive
hour, pieces per productive hour, percent productive hours (P), and costs per M bd.ft.
(C). Table 1 shows these data for the units that were either completed or had sub-
stantial volumes of timber removed. The following regression analyses on these data,
based on unit averages, explains much of the variation in costs and production.

Costs in dollars per M bd.ft. were supplied by Boise Cascade's accounting depart-
ment. When total yarding cost per M bd.ft. (C) was used as the dependent variable and
regressed on average piece size (B = bd.ft./piece), the resulting regression equation was

$$C = 92.77 - 0.1564B \text{ or in metric terms} \tag{1}$$
$$C(\frac{\$}{m^3}) = 20.50 - 7.639B(\frac{m^3}{piece})$$

with $R^2 = 0.5093$.

With volume per acre (V) as the independent variable

$$C = 83.89 - 3.458V \text{ or in metric terms} \tag{2}$$
$$C(\frac{\$}{m^3}) = 18.54 - 0.0683B(\frac{m^3}{ha})$$

and the $R^2 = 0.8339$. Multiple regression using piece size and volume per acre both as
independent variables yielded the equation

$$C = 101.90 - 0.0920B - 2.834V \text{ or in metric terms} \tag{3}$$
$$C(\frac{\$}{m^3}) = 22.52 - 4.493 \frac{m^3}{piece} - 0.0560(\frac{m^3}{ha})$$

with an $R^2 = 0.9831$.

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Table 1.--*1971 data--balloon logging*

Unit #	(V)[1] Volume M bd.ft./acre (m³/ha)	(B) Piece size bd.ft./piece (m³/piece)	(C)[2] Yarding cost $/M bd.ft. ($/m³)	Turns per productive hour	Pieces per productive hour	(P)[3] Percent productive hours
1	11.0 (123)	350 (1.58)	38.97 (8.61)	5.02	11.34	76.9
2	6.3 (70)	236 (1.07)	59.73 (13.20)	4.14	11.42	63.7
3	5.0 (56)	259 (1.17)	65.77 (14.54)	4.59	11.35	59.7
14	7.3 (81.6)	192 (0.87)	63.70 (14.08)	4	4	4
13	11.9 (133)	216 (0.98)	49.62 (10.97)	5.89	16.33	72.3
16	13.0 (145)	293 (1.33)	37.10 (8.20)	6.35	19.22	69.5

[1] Average volume harvested on the unit in thousand board feet per acre.
[2] The cost in dollars per thousand board feet for moving the logs from the stump to the landing (this includes balloon yarding, changing cable roads, landing costs, as well as costs for yarder downtime).
[3] Total yarding hours divided by total hours logged by yarder times 100.
[4] Data were not collected as this was the first unit logged on the sale.

Equation (1) shows that costs decrease as average piece size increases with this single variable explaining approximately one-half of the cost variation. Average piece size is used by many logging companies as one criterion on which to estimate costs of logging. From a physical standpoint, it also is reasonable to expect that costs would be lower when fewer pieces had to be handled per M bd.ft. of production.

In equation (2), volume per acre explained 83 percent of the variation in cost per M bd.ft. This relationship shows that volume per acre is the most important factor for predicting the cost of balloon yarding. At first glance, volume per acre seems to explain more of the cost variation than would be expected. Further analysis yielded a relationship between percent productive hours (P) and volume per acre

$$P = 53.50 + 1.58V \text{ or in metric terms} \qquad (4)$$
$$P = 53.50 + 0.1413(\frac{m^3}{ha})$$

with an $R^2 = 0.6793$. This equation shows that the percent productive hours increases as the volume per acre increases. Based on field experience, it is reasonable to expect

that the number of road changes and percent down time for moving equipment decreases as the number of logs yarded on a given logging set increases. The cost per M bd.ft. decreased $1.568 for each 1 percent increase in percent productive hours as shown in equation (5) where cost was regressed on percent productive time

$$C = 157.50 - 1.568P \text{ or in metric terms} \tag{5}$$

$$C = 34.81 - 0.3465P$$

and $R^2 = 0.7263$. This relationship quantifies the cost of nonproductive time on this logging operation.

Equation (3) yields a simple but useful relationship for predicting yarding costs based on both volume per acre and piece size. These two variables should provide a good estimate since they explain 98 percent of the variability in cost based on the 1971 logging data. It should be kept in mind that equations (1) through (5) should be used when the variables are within the range of the data given in table 1, and any extrapolation should be used with care.

These relationships based on gross data quantify factors that affect balloon logging and should be followed through with a larger range of data so that the prediction equations' range can be extended. Also, the equations should be verified by data from other balloon logging sites. It is expected that these prediction equations would not be as good for other areas since there are many factors which affect logging costs that are not included in the equations. These factors can be more or less constant at one logging site, but vary greatly between logging sites. Examples of some of these factors are local wage rates, fuel costs, weather, terrain, timber type, and harvesting technique. Another factor to keep in mind when using the cost figures is that they should be escalated for inflation because they are based on 1971 cost figures.

As shown in table 2, balloon yarding costs ranged from $42.44 to $54.49 per M bd.ft. If the site had been logged with a skyline (elevated cable) yarding system, costs would have been about $20 per M bd.ft. Not included in the costs of skyline yarding is the cost of the extensive road system required, which would have raised total costs considerably.

Yearly average cost and production figures did not vary greatly. It was hoped that costs would decrease from year to year as experience with the balloon system was gained, but this was not the case. Production did increase in the number of pieces per hour, but the average piece size was smaller during the last year. Some of the more difficult yarding chances were delayed until the latter part of the logging, and the sale was completed using a helicopter for yarding. This modification to the original contract was done with the approval of the Forest Service. The logging was done with a Boeing Vertol-107 helicopter, which has a load capacity of approximately 8,000 lb (3,629 kg). The helicopter logging subcontractor received approximately $90 per M bd.ft. ($19.89/m^3) to get the logs to the deck. This cost is higher than the average balloon logging cost, but with the difficulty of the logging sets, it was felt to be justified. Also, the production with this size helicopter is about 100 M bd.ft. (452 m^3) per day, which is approximately three times the balloon daily production; thus, the logging was completed expeditiously.

Based on the comparison of the helicopter and balloon logging, Boise Cascade decided to sell their balloon logging system and bought their own helicopter. This decision was based on the Forest Service plans to require aerial logging on substantial volumes of timber in the southern Idaho Batholith. Evidently, Boise Cascade believed that owning their own helicopter would be more economical--the production would be much greater and the helicopter would be a more flexible system as compared to the balloon system in the Idaho Batholith.

Table 2.--*Yearly balloon logging statistics*

Year	Timber removed M bd.ft. (m³)	Percent productive hours[1]	Turns per productive hour	Pieces per productive hour	Balloon yarding cost $/M bd.ft.[2] ($/m³)	Total cost to get logs to deck $/M bd.ft.[3] ($/m³)
1971	3,533 (15,986)	67.0	5.30	14.99	47.44 (10.48)	62.78 (13.87)
1972	6,290 (28,462)	67.3	6.08	17.59	42.44 (9.38)	58.33 (12.89)
1973	3,233 (14,629)	70.6	5.27	20.75	54.49 (12.04)	72.37 (15.99)

[1] Total yarding hours including delays divided by total hours logged by yarder times 100.
[2] Balloon yarding cost including landing and road change costs.
[3] Total cost to get the logs to the deck (this includes cutting, yarding, road changes, landings, slashing, mobilization, administration, and bedding costs, but does not include stumpage costs).

The helicopter system of logging is a high consumer of fuel compared to balloon logging. This could lead to a relative change in the economics of helicopter logging, if fuel prices continue to rise or if fuel shortages occur.

At present, the balloon system would appear to have applications in areas of the Rocky Mountains where the terrain is not as dissected as Anderson Creek and timber volumes per acre and average piece size are sufficiently large to justify this system economically. The use of clearcutting harvesting techniques would help raise volume per acre when environmentally sound. However, for this sale, the need for an overstory removal harvesting technique made the economics of balloon logging marginal when compared to prices received for finished timber products.

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    A site on the Idaho Batholith where conventional logging and road-
builing had produced massive erosion was experimentally logged with
a balloon yarding system. Balloon logging proved feasible, environ-
mentally acceptable, but economically unattractive. The extreme
steepness of the terrain and the selective cutting (overstory removal)
contributed to high yarding costs.

KEYWORDS: timber harvesting, yarding, environment, balloon logging.

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