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The Series

THE ENGINEERING FIELD NOTES SERIES is published periodically as a means of exchanging engineering-related ideas and information on activities, problems encountered and solutions developed, or other data that may be of value to Engineers Service-wide.

Submittals

Field personnel should send material through their Regional Information Coordinator for review by the Regional Office to ensure inclusion of information that is accurate, timely, and of interest Service-wide.

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The ROADS Working Group

The ROADS Working Group recipients of a U.S. Department of Agriculture Certificate of Merit: (1) Joy Berg (left) receiving from Floyd (Butch) Morita, Regional Forester (R-9); (2) David Jolly (left) from Sotero Muniz, Regional Forester (R-3); (3) Dan Erkkila (right) from Chief Robertson; (4) Jim Davis (right) from Zane Smith, former Regional Forester (R-5); (5) Walter (Tom) Henry; (6) John Lowe (right) from Chief Robertson; (7) Larry Hayden (left) from George Olson, Supervisor, National Forests in North Carolina; and (8) Bruce Meinders (right) from John Alcock, Regional Forester (R-8).

Road Program Costs—Continuing Efforts Addressing the Issue

Over the past year, Engineering Field Notes has highlighted various efforts that Engineering has undertaken to help control and reduce the costs of managing the Forest Service transportation system. To name a couple--the ROad Analysis & Display System (ROADS) and the Road Technology Improvement Program (RTIP). Another example of how Engineering is reducing costs is the way in which Engineering employees are sharing information.

ENGINEERING CLIP SHEET

One fine example of this sharing is Region 6's Engineering Clip Sheet (ECS). Produced informally--a few times a year, or whenever needed--ECS has been around for approximately 3 years. Each of the 20 Region 6 Forests has an ECS coordinator who submits short articles (usually just a few paragraphs) or requests for advice/information to the Regional Coordinator, Ken May.

Aside from being a fine way to let Engineering personnel know what is going on around the Region, ECS provides a way for individuals to seek and find expert advice from others. For example, some requests for advice and information that were in one recent issue of ECS concerned the following:

(1) Construction techniques through lava.

(2) Information on low-pressure float valves.

(3) Practicality and Regional availability of a trail rock crusher.

(4) Availability of horizontal drilling specifications in Forest Service format for standard horizontal wells.

Engineering employees throughout the Region read the ECS and respond with advice over the Data General system to those who need the information--sometimes within just a couple of hours of ECS distribution. Engineering Clip Sheet coordinators are justifiably proud of this ECS "Data General Network."

Each ECS issue usually concentrates on six major areas:

(1) Technology Transfer

(2) Road Systems

(3) Management

(4) Geotechnical Developments

(5) Roads

(6) Facilities

The June 1987 issue was full of useful information on each of the above areas.

If you would like more information on Region 6's Engineering Clip Sheet--perhaps you would like to start up your own--contact Ken May, Region 6 ECS Coordinator, at KEN MAY:R06F18D03A. EFN

If we truly want to reduce the costs of managing our transportation network, save time, and avoid reinventing the wheel, it is essential that each of us in the Forest Service take advantage of the opportunities that the ECS and other similar media throughout the Forest Service provide.

Let EFN readers know how your Forest or Region is going about the important job of sharing information. If it works for you, it may work for others!

--Editor, EFN

Productivity Gains From Computers

Jerry Bowser
Branch Chief
Systems Operations, Analysis, & Development
Washington Office

The Forest Service has a long history of effectively using computers for engineering applications. It is a good thing, because without them, we would have been unable to make huge gains in productivity. We are accomplishing higher quality engineering than in the past at a fraction of the costs. One major benefactor has been road design, but for years, we also have used computers to advantage for inventories, network analysis, simulation models, geometronics, and mathematical computations.

Until 1983, we primarily depended on centralized processors operating in batch, such as the IBM 650, the IBM 1401 at the FHwA, the CDC 3100, and, more recently, the series of Univac 1100 at the Ft. Collins Computer Center (FCCC). In those days, most engineers did not directly interact with the computer, instead depending on specialists who were computer literate, punched the cards, and gave the necessary commands.

TODAY'S TECHNOLOGY

The 1980's have introduced distributed processing to every organizational level. The introduction of the Data General system has totally changed the way we handle information in the Forest Service. The explosion of personal computers, portable computers, and super minicomputers at affordable prices has placed the technology at the user's desk. This has effectively made the entire workforce computer literate--since there is a keyboard at most people's fingertips. Users are not satisfied with batch operations anymore, expecting interactive capability in all software. Users are also demanding higher quality hardware and software products--they realize the proliferation of capabilities available within the marketplace.

With this state of technology, Forest officers can analyze many more alternatives quickly and achieve precision in a far shorter time period than was possible just a few years ago. Professionals do not have to be bogged down in the drudgery of detail that consumed so much of their time in the past. Engineers know that their calculations and designs must be accurate so that their civil works provide low-cost service throughout the life cycle, while protecting public safety. Accuracy also minimizes the costs of contractor claims during construction.

The Data General system serves as the medium for corporate information sharing, and it has become as essential as the telephone. It provides new "highways" for rapid communications that were never before available.

Fifteen years ago, we had HP 9100 systems in a few locations, but the purchase of HP 9020 systems (Lot 7) specifically for the preparation of road and timber sale project plans was the first large move toward stand-alone systems. Out of this came an important piece of software for road design--the Forest Level Road Design System (FLRDS).

More recently, Regions have acquired a variety of systems, including the HP 150, AT&T 6300, and IBM AT. Road design is being accomplished with software products like HANS_ON and Lumberjack. Users throughout the Nation have automated drafting capabilities for facility and road plans as well as for survey platting.

We are now working toward the infusion of multitasking workstations into the Forest Service. These will permit multiple, simultaneous, stand-alone operations with file transfer capability totally integrated with the corporate system. These systems will allow users to move the more resource-intensive operations from the main system or perform operations on several CPU's while maintaining the corporate information structure.

This tremendous change in our computer environment was guided by having a national implementation plan for the Data General system and by the results of the SyMRIP study in 1984-85. Although the proposed alternative from SyMRIP did not result in a nationally sponsored initiative as had been hoped at the time, it did help trigger the delegation of $100,000 per procurement for ADP equipment to Regional Foresters. According to Jim Webb's (Associate Deputy Chief, Administration) letter of January 3, 1986, this delegation was made to "pursue local high priority needs complementary to and compatible with the backbone information framework provided by the Data General systems. Some needs, such as those identified in the SyMRIP report, certainly fall into this category" The study proposed a mix of Data General corporate system upsizings, stand-alone minicomputers, and personal computers--all with appropriate peripherals, such as plotters, digitizers, and graphics terminals.

PRODUCTIVITY IMPROVEMENTS

Although not all the needed computer capability is in place, the productivity gains are apparent. In the road program, Engineering support unit costs since 1983 have remained fairly constant. This is remarkable when one realizes that the outputs have been declining during that period and that many support costs, such as rents, utilities, Land Management Planning, and so forth, remain relatively constant and do not fluctuate with outputs. The national costs for support have declined as follows:

Year	Expenditure (M)	Adjusted to Constant 1983 Dollars (M) (4%)
1983	$153,233	$153,233
1984	151,669	148,726
1985	146,649	138,275
1986	132,955	128,567

Several factors have contributed to reducing the Engineering support expenditures:

(1) There is an increase in the use of field designs for local roads.

(2) Through productivity improvements, there has been a 30-percent reduction in Engineering personnel, most of which was associated with the road program.

(3) A radical shift in workload from FCCC to local computers has occurred. The following chart demonstrates that migration:

Year	FCCC Executions
1981	104,852
1984	80,034
1986	39,968

This change alone has decreased the design cost of roads from $1,500 to $2,000 per mile to $200 to $600 per mile. While processing costs are less, quality has improved--interactive graphics permit instantaneous evaluation of results; plots are cheaper; the programs are easier to run; and the output packages are more usable.

There are similar gains being made in other Engineering activities. For example, drafting costs for facilities have been reduced through the use of CAD by as much as 70 percent. After a series of standard plans are produced, both design and drafting costs will be further reduced and the potential for sharing standards between Regions is increased. Through micro-based network analysis, we have transportation evaluation tools that can quickly compare alternatives for the decisionmaker. We are even seeing some of the inventories migrating to local systems, which will permit instant retrieval capability and user-defined report flexibility.

The FUTURE

As impressive as these gains are, they are but samples of the more dramatic gains to be made in the future. Graphics scanners, optical storage, pictureware, expert systems, and relational data bases are but a few of the products that will soon be available. Low-cost mass storage is an absolute necessity to our information management future.

These future technologies and the capabilities they will bring are important because of the need to provide more and better information to the public. Forest management is more complex than ever because there is more interest in the "what we do" and the "why we do it." We must be able to convincingly display alternatives, costs, and the rationale for decisions if we are to maintain the public's support. EFN

Another Look at Bidtab

Edmund C. Tarver
Highway Engineer
Regional Office, Region 8

INTRODUCTION

As the products of new technology are incorporated and become operational, they allow for the opportunity to rethink and apply some "not so new" methods and technology that have been around for several years. This is particularly true with the interaction of the Data General (the new) with the Bidtab System (the not so new).

BACKGROUND

Bidtab has existed for several years. Basically, it is a data base residing at the Ft. Collins Computer Center (FCCC). Its purpose is to store specific information collected during the bid phase of the public works procurement process. Then, using S2K language, statistical information is extracted and presented to suit the user's needs. Usually, the statistical reports that are generated can be useful in developing engineering cost estimates. The reports, however, may be useful to others as well.

INCREASED CONVENIENCE

Before early 1986, the data for Bidtab were collected and transmitted through manual input or through the use of the Contract Information Management System (CIMS), as it existed on the TI 990 equipment. The disadvantages of manual input are evident, and even though the introduction of CIMS on the TI 990 was a tremendous boost, there still were serious problems with its availability and ease of operation.

CIMS on the Data General has eliminated most of the problems associated with collecting and transmitting data to Bidtab because of the corporate nature of the Data General. CIMS provides a convenient means of collecting the information on a system that is readily available and that can easily transmit data as necessary.

PROCEDURE

The first step is to load the Regional pay items into Bidtab. Next, cooperating Forests enter their project data (that is, the estimate phase) into the Data General CIMS. After the project is advertised and bids are received, bids are posted in CIMS. As this is done, a runstream file consisting of 16 data components is automatically established. The components consist of such information as pay item number, bid unit price, State and county ID, terrain type, and so on.

After contract award is accomplished in CIMS, it automatically mails the runstream file via CEO to the Regional CIMS coordinator. The coordinator scans the file to ensure that the data are consistent with those already stored at FCCC. The file is then forwarded electronically to FCCC and loaded into the Bidtab data base. Once the process is started, it continues with minimal impact.

REPORTS

Figures 1 and 2 are samples of two reports derived from Region 8's Bidtab data base. Both reports were developed to aid the estimator in establishing project cost estimates.

The first report (figure 1) is a listing of all active pay items for fiscal years 1985 and 1986 (any period of time could be selected as long as data existed). The listing summarizes minimum and maximum quantities, along with the average winning bid and the average of all bids. Frequency of use for each pay item is indicated by the number of projects using that item number. Also, the number of bids is shown for each item.

This report can be useful in providing general information concerning unit prices for specific items. This is especially true if the item is seldom used. The report also allows the identification of frequently used pay items that can lead to summaries, such as the one shown in figure 2.

The report in figure 2 summarizes unit prices for specific pay items as a function of quantity and terrain type. Quantity is a major influence on bid unit prices (that is, normally the larger the quantity--the higher the efficiency--the lower the price). That correlation is borne out in this summary for Pay Item 203(02), which is one of the 16 most frequently used items in Region 8.

Other factors that can affect unit costs are project accessibility, site topography, and climatic conditions. In Region 8, these factors have been represented in the definitions of nine terrain types. Examples of the types are FLAT1, FLAT2, FLAT3, USDA - FS-R8

HISTORICAL BID INFORMATION
PAY ITEM LISTING WITH AVERAGE BID UNIT PRICES
REGIONAL SUMMARY

PAGE 1
05/13/87

PAY ITEM	ITEM NAME	UNIT	PROJ	BIDS	MINIMUM QUANTITY	MAXIMUM QUANTITY	AVG WIN. BID	AVG ALL BIDS
201(02)1-4	CLEARING & GRUBBING SLASH TREATMENT 1 OR 4	STA.	5	30	17.36	169.38	66.64	77.52
201(02)4	CLEARING & GRUBBING SLASH TREATMENT 4	STA.	6	24	14.13	85.50	48.57	58.11
201(04)	CLEAR & GRUB DISPOSAL T&L[-] LOGS[-] STUMPS[-]	L.S.	9	59	1.00	1.00	1817.94	3419.71
201(04)4	CLEARING & GRUBBING SLASH TREATMENT 4	L.S.	7	20	1.00	1.00	765.00	1888.00
201(04)5-8	CLEARING & GRUBBING TOPS&LIMBS(5) LOGS(8) STUMPS(5)	L.S.	1	4	1.00	1.00	1500.00	2369.75
201(10)	GEOTEXTILE	L.F.	1	3	1155.00	1155.00	2.00	1.83
202(01)	REMOVAL OF STRUCTURES AND OBSTRUCTIONS	L.S.	9	26	1.00	1.00	1277.92	1433.65
202(02)A	REMOVAL OF BRIDGE	EA.	6	14	1.00	2.00	4352.00	4765.43
202(02)B	REMOVAL OF PIPE CULVERTS	EA.	2	5	3.00	3.00	40.00	96.39
202(02)C	REMOVAL OF CATTLEGUARD	EA.	2	4	1.00	2.00	275.00	162.50
202(02)D	REMOVAL OF DROP INLETS	EA.	1	4	3.00	3.00	75.00	148.75
202(02)G	REMOVAL OF METAL GATE	EA.	2	10	1.00	1.00	17.50	88.00
202(02)P	REMOVAL OF PIPE CULVERTS, ALL SIZES	EA.	8	26	1.00	14.00	134.00	137.69
202(02)S	REMOVAL OF SMALL SIZED [----]" PIPE CULVERTS	EA.	6	26	1.00	7.00	85.83	130.00
202(03)B	REMOVAL OF CULVERT	L.F.	2	2	48.00	50.00	17.50	17.50
202(03)FBW	REMOVAL OF FENCE BARBED WIRE	L.F.	1	3	1.00	1.00	250.00	450.00
202(03)S	REMOVAL OF SURFACING	L.F.	1	2	13024.00	13024.00	0.60	0.54
202(04)A	REMOVAL OF PAVEMENT	S.Y.	2	7	140.00	913.00	2.13	3.11
202(05)B	REMOVAL OF CULVERTS	L.S.	2	6	1.00	1.00	137.50	500.17
202(05)BR	REMOVAL OF BRIDGE	L.S.	1	2	1.00	1.00	9800.00	12900.00
202(05)G	REMOVAL OF EXISTING GATES	L.S.	1	1	1.00	1.00	100.00	100.00
203(T)	QUALITY CONTROL TESTING	L.S.	2	3	1.00	1.00	800.00	700.00
203(01)	EXCAVATION - PLACEMENT METHOD 1	C.Y.	49	218	16.00	31377.00	2.38	2.68
203(02)	EXCAVATION - PLACEMENT METHOD 2	C.Y.	42	260	35.00	47993.00	2.28	2.74
203(03)	EXCAVATION - PLACEMENT METHOD 6	C.Y.	5	14	604.00	19552.00	2.41	2.81
203(04)	EXCAVATION - PLACEMENT METHOD 4	C.Y.	10	36	4.69	5460.00	6.06	5.66
203(07)1	EXCAVATION - PLACEMENT METHOD 1	STA.	16	85	10.00	169.38	134.84	195.54
203(07)2	EXCAVATION - PLACEMENT METHOD 2	STA.	21	84	.49	143.51	282.96	466.78
203(07)3	EXCAVATION - PLACEMENT METHOD 3	STA.	6	14	.50	176.34	115.24	274.83
203(07)4	EXCAVATION - PLACEMENT METHOD 4	STA.	7	47	.04	137.28	339.27	222.07
203(08)1	EXCAVATION - PLACEMENT METHOD 1	MI.	5	26	.74	3.05	3981.12	6745.67
203(08)2	EXCAVATION - PLACEMENT METHOD 2	MI.	1	1	.85	.85	4224.00	4224.00

R8-BTRS-R49
FEB 1987

Figure 1.--Report listing all active pay items for fiscal years 1985 and 1986.

USDA - FS-R8

HISTORICAL BID INFORMATION
SUMMARY OF AVERAGE BID UNIT PRICES
BY TERRAIN TYPE & QUANTITY RANGE
REGIONAL SUMMARY

PAGE 1

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PAY ITEM # 203(02) DESCRIPTION - EXCAVATION - PLACEMENT METHOD 2 UNIT OF MEASURE: C.Y.

TERRAIN TYPE	....0-3000 (CYS)....			....3000-9000 (CYS)....			...9000-18000 (CYS)..			...18000-30000 (CYS)..		
	AVG WIN. BID	AVG ALL BID	NO (PROJ)	AVG WIN. BID	AVG ALL BID	NO (PROJ)	AVG WIN. BID	AVG ALL BID	NO (PROJ)	AVG WIN. BID	AVG ALL BID	NO (PROJ)
FLAT1	1.83	4.67	3			0			0			0
FLAT2	3.50	3.08	2			0			0			0
INTER2			0	1.28	1.34	1			0			0
MTN1			0	3.00	2.70	4			0	2.50	2.52	1
MTN2	2.47	3.13	18	1.76	2.54	16	2.05	2.24	6	1.27	1.60	5
MTN3	3.16	2.79	6	2.92	2.52	4			0			0
			(====)			(====)			(====)			(====)
ALL	2.62	3.23	29	2.12	2.54	25	2.05	2.24	6	1.47	1.89	6

R8-BTRS-R16
FEB 1987

Figure 2.--Report summarizing unit prices for specific pay items as a function of quantity and terrain type.

INTER1, and MTN3. In this series, FLAT1 would be the most difficult construction in the group of "FLAT" area (that is, the coastal plains), and FLAT 3 would be the easiest. The other two areas, "INTER" (intermediate) and "MTN" (mountain), are defined in a similar manner.

So far, the correlation of bid unit prices with terrain types has not been good, as seen in this example. Perhaps the correlation will improve as experience is gained in classifying projects using the new definitions.

CONCLUSION

Bidtab is not new, but its use has been made easier with the introduction of CIMS on the Data General. With the needs of the field and others in mind, some imagination, and skill, useful reports may be generated from data that would otherwise be underutilized.

EFN

For more information, contact Ed Tarver at FTS 257-2470 or by the Data General at E.Tarver:R08A.

Epoxy Injection Repair of Crane Lake Dam

Jack Mielke
Civil Engineer
Mark Twain National Forest, Region 9

A search for an economical solution to a badly cracked and deteriorating concrete dam led the Mark Twain National Forest Engineering Staff to a potentially valuable tool for many types of concrete repair--epoxy injection. Epoxy technology can now be applied effectively to problems involving sealing, bonding, grouting, patching, protecting, and overlaying concrete. It is cost-effective, minimizes downtime, requires simple equipment, and is easy to use. Although our first epoxy repair project was a dam, the experience and knowledge gained should prove useful in numerous situations.

The DAM

Crane Lake is a recreational reservoir approximately 80 miles south of St. Louis, Missouri. The normal pool area is 125 acres, with depths to 40 feet.

The dam includes an earthen embankment 220 feet long by 46 feet high and vertical-face, concrete spillways 73 feet long on the left (northeast) end and 100 feet long on the right (southwest) end (figure 1). Spillway heights vary from 4 feet to 14 feet, and each structure abuts rock ledge to the outside and a concrete retaining wall on the inside. The retaining walls contain the embankment and protect it from spillway discharges. Each wall extends downstream over 100 feet from the spillway. The right spillway is further reinforced with four concrete buttresses, two of which form a chute for a stop-log outlet works. All spillway walls and retaining walls are a minimum of 1 foot thick.

The PROBLEM

When the Forest Service acquired the dam in 1973, the dam had been privately constructed and reconstructed twice by the owners. At the time, some minor cracking was noted in the spillway concrete. Over the next 10 years, some additional minor cracking was noted but did not pose an immediate threat to the structure. In 1985, however, a huge snag drifted against the right spillway during high

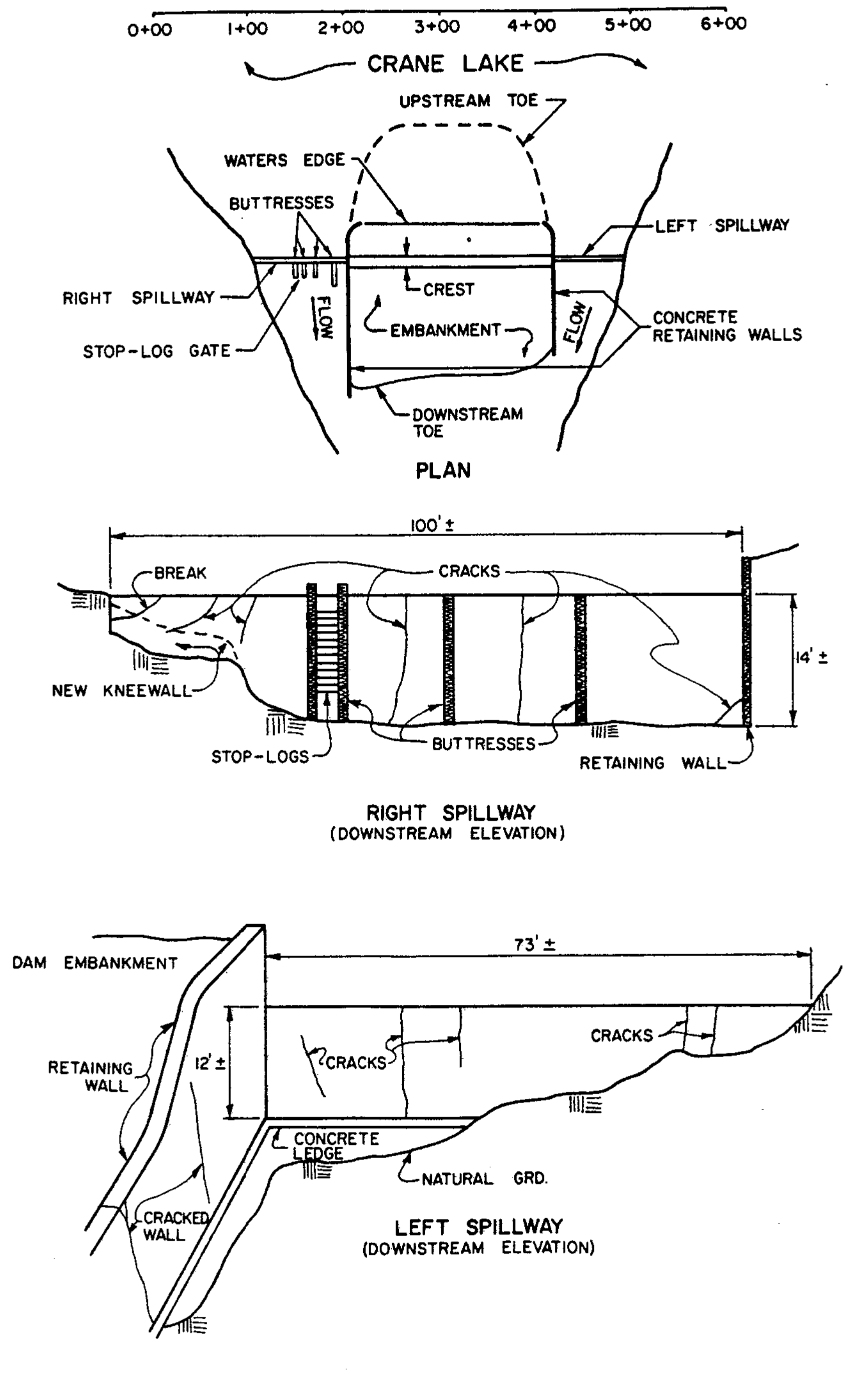

Figure 1.--Crane Lake Dam repairs plan and spillway elevations.

water. The 44-foot section between the abutment and the first buttress was severely damaged. Several new cracks appeared, and a segment of the wall, approximately 10 feet long by 2 feet high, was broken loose and displaced up to 2 inches.

The situation was deemed hazardous, so the lake was drawn down 8 feet below normal pool. This reduced the pool area to about 50 acres, leaving extensive mudflats.

The HEALING PROCESS

A contract for repairs was awarded in September 1986 at a total price of $16,679. Working only 6 days during the first 2 weeks of November 1986, the contractor constructed a concrete knee wall 32 feet long by 2 feet high, which was dowelled into bedrock to reinforce the badly damaged right spillway. The contractor then injected epoxy grout, full depth, into 213 linear feet of cracks to both seal and bond the breaks. Figures 2 and 3 contain photographs of the cracks in the dam and some of the repair process.

The contractor used methods, materials, and equipment developed by the Adhesive Engineering Company (AEC). The following information applies to AEC's techniques and products.

The repairs involved the structural concrete bonding (SCB) process, which can be applied to fill and bond cracks as small as 0.002 inches wide and up to 20 feet or more deep. The injected liquid epoxy cures to a solid, which provides a seamless barrier that is unaffected by water and resistant to most chemicals. The epoxy forms a bond that is stronger than the concrete. The material will encapsulate and protect reinforcing steel near injected cracks from further corrosion. SCB uses concressive structural epoxy adhesives--a family of materials able to handle a variety of needs, such as high-temperature or underwater applications.

The most surprising aspect of the Crane Lake epoxy work was the small size, simplicity, and portability of the equipment. All the equipment and material for the work fit easily into the back of a $\frac{1}{4}$-ton pickup. The pump unit is basically a steel box, about 20 inches by 16 inches by 10 inches high, with wheels and a handle. It can be maneuvered by one individual, and two people can easily lift it over obstacles or place it in elevated locations. The dual metering pumps are powered by any 120-volt AC

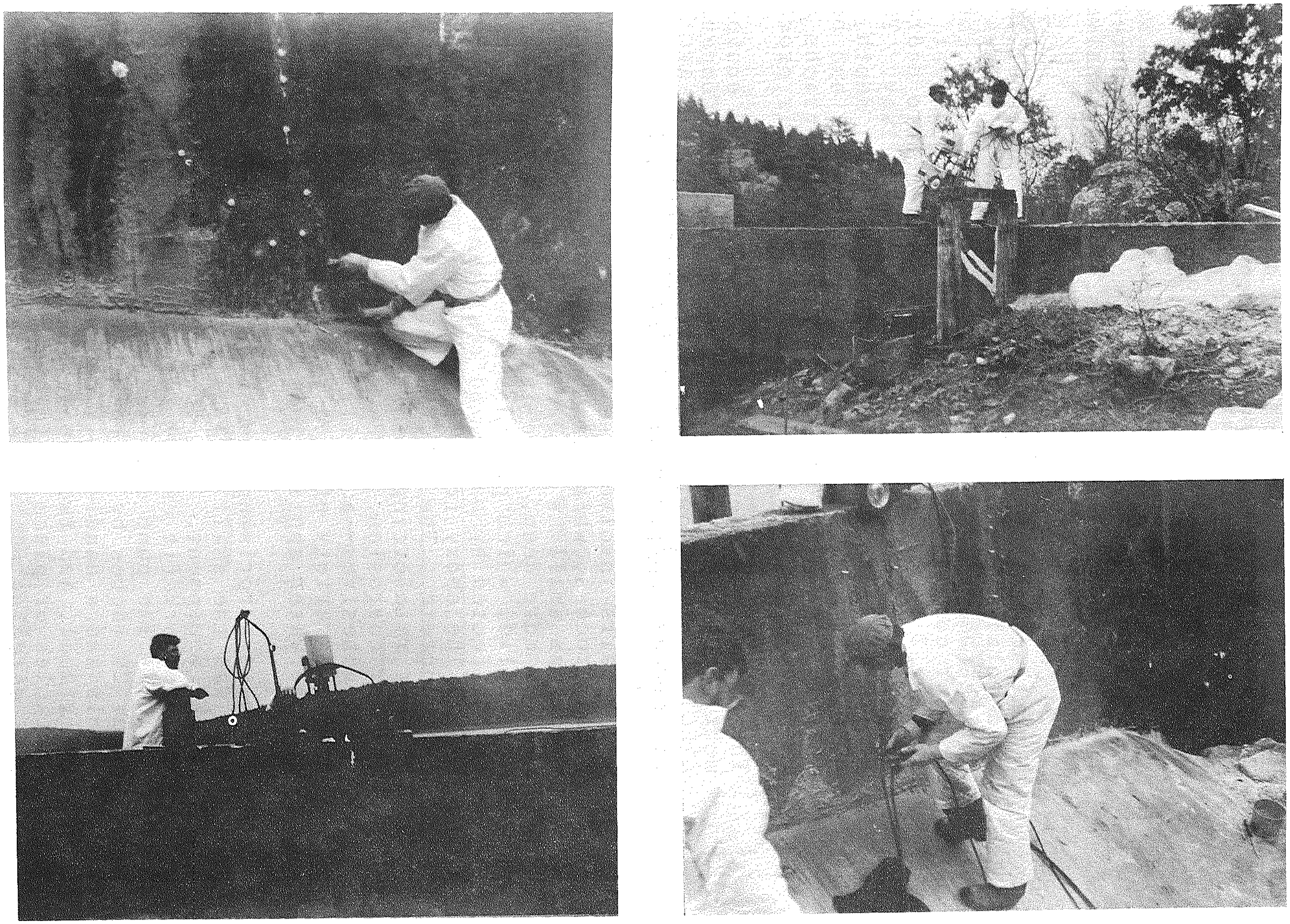

Figure 2.--Photographs of Crane Lake Dam and the repair process: (a) surface sealing the cracks (note the injection port spacing); (b) moving pump unit into place (note the generator by the pile); (c) testing and adjusting the pump unit (note that crack to the right is cleaned but not sealed); and (d) epoxy injection under way (mixing head in right hand and pressure control in left hand).

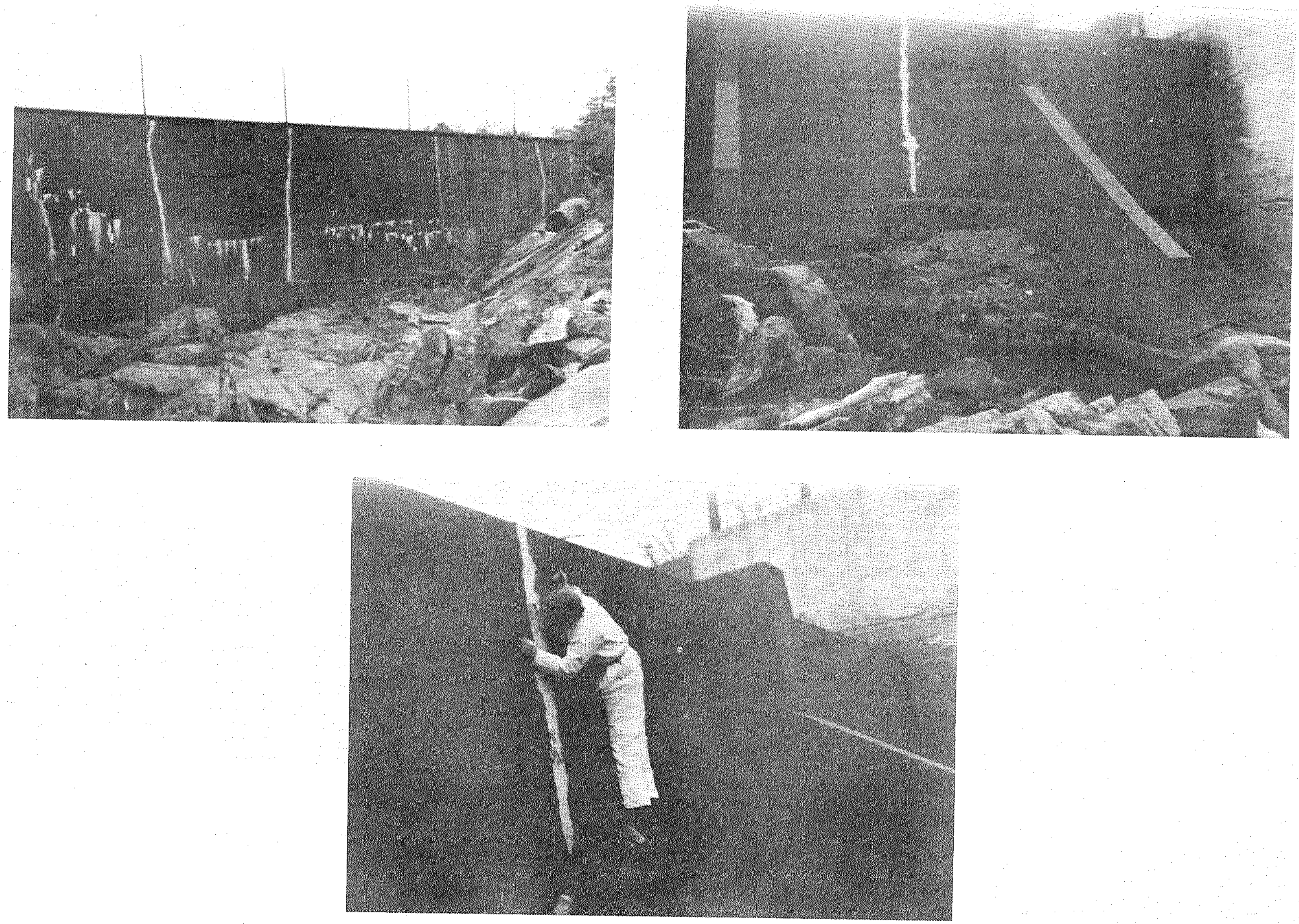

Figure 3.--More photographs of the dam and repair process: (a) left spillway (note the six vertical cracks surface sealed); (b) major crack in right spillway (note the buttresses); and (c) refastening injection port blown out by pressure.

electrical source. At Crane Lake, a small Winpower 4000 RE generator was used.

The epoxy resin and hardener are delivered separately through $\frac{3}{8}$-inch ID rubber hoses to a pistol-shaped mixing head. The head is usually manipulated with one hand. Pumping pressure can be varied with a separate hand-held device. Epoxy materials are fed to the pumps from replaceable plastic containers that fasten to the top of the pump unit.

Thus, the entire injecting operation can be done by one individual; however, a two-person crew is generally more efficient. Before each day's work, and during the grouting, the equipment is checked to ensure that the pressure is holding and that the exact design ratio of epoxy hardener and resin is reaching the mixing head. These tests are simple and quick and can usually be performed with the equipment in place.

Preparation of the cracks or surfaces is generally the most time-consuming and critical part of the operation. On the Crane Lake project, a four-person crew spent most of 3 days and a two-person crew parts of 2 days on surface preparation. The exterior surface along the crack must be cleaned and then sealed to prevent epoxy from leaking out during or after injection. Several different products are used for surface sealing, depending on crack size, weather, and other variables. Most of these are fast curing--5 minutes or less to 1 hour. When possible, the back side of cracks extending through the structure is also sealed up to prevent epoxy loss. This surface seal is critical to contain the pressurized grout and force it through the cracks. However, after the injected grout hardens, the surface seal can be easily removed to facilitate esthetic improvements to the repaired area.

Immediately before or along with the surface sealing, injection ports, which are small plastic nipples with a flange on the base, are centered over the crackline and glued in place. The flange is covered over with the surface sealant, which then holds the port against the back pressure during grouting. The spacing of the ports is generally about equal to the structural thickness; the theory is that, when the grout injected in a port reaches the next port, it should have traveled through the structure an equal distance in every direction. On vertical surfaces, such as the Crane Lake Dam, the injection proceeds from bottom up on each crack. When grout starts running out the next port above the one being injected, the "gun" is moved to the leaking port, and the vacated port is plugged up.

The actual injection process is very simple. The operator places the gun barrel over the port nipple and pulls the trigger. The rate of injection varies greatly because of differences in epoxy materials, viscosity, crack width, and structural thickness. The operator can control the rate by varying the pump pressure, up to 200 pounds per square inch (psi). As previously noted, the Crane Lake project included injecting 213 linear feet of cracks. The injected walls averaged about 16 inches thick, and the cracks were mostly tight, with some approaching the 0.002-inch lower limit. Of the total project time, less than 2 days were spent actually injecting the epoxy. This production rate was relatively slow because of poor weather, access problems to parts of the work, and some unusual equipment problems.

CONCLUSION

Epoxy technology offers a quick and simple solution to many types of concrete problems, including sealing, grouting, loading, patching, and overlaying, at a fraction of the cost of typical concrete repairs. Since the Forest Service maintains thousands of buildings, bridges, and dams, we should be using this technology as much as possible. Instead of tearing out old concrete structures, there are undoubtedly many opportunities to "glue 'em back together."

EFN

North Boat Ramp—Diamond Lake, Oregon

Robert Nixon, Retired
Project Engineer
Umpqua National Forest

INTRODUCTION

In 1984, the Forest Service decided to replace the north boat ramp at Diamond Lake. The ramp is one of the 10 most used fresh water ramps in Oregon, averaging 19,400 recreation visits per year. Diamond Lake is about 3½ miles long and 1½ miles wide at 5,183 feet elevation 6 miles north of Crater Lake National Park and 85 miles east of Roseburg, Oregon (figure 1). The ramp that existed then consisted of a floating dock with two lines of deteriorated precast slabs. The dock needed to be removed each fall and installed each spring, and it required extensive repairs or replacement.

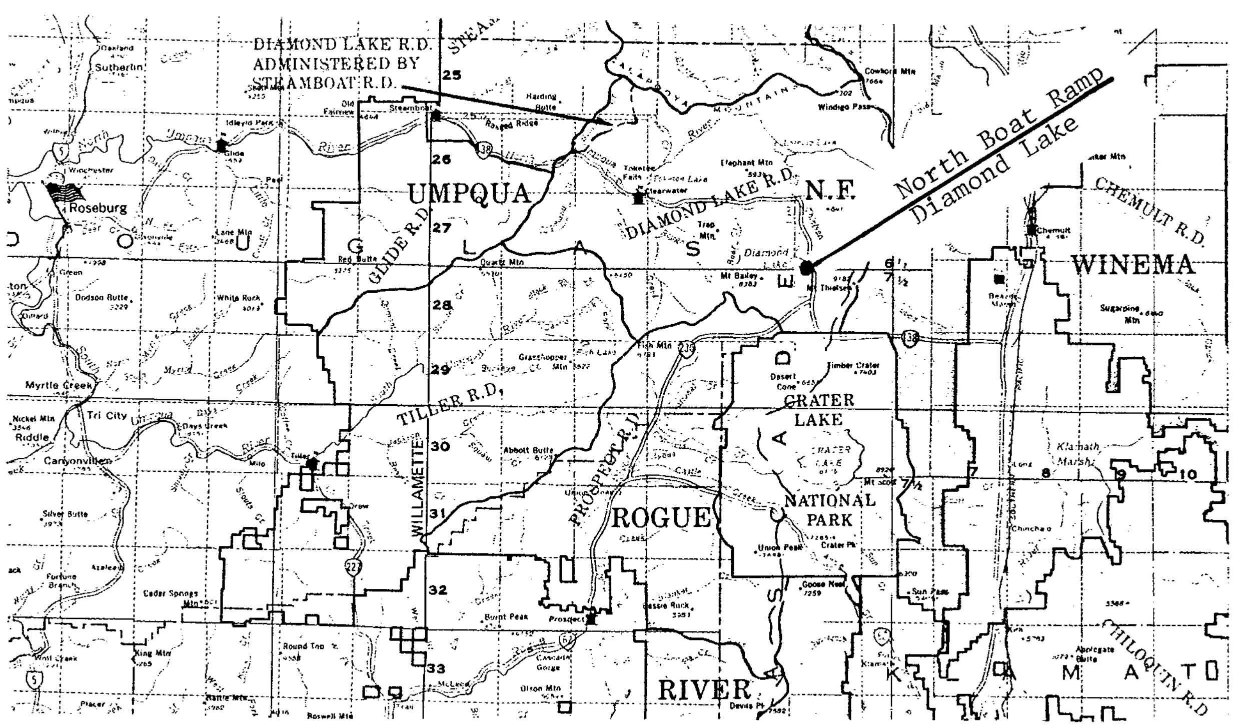

Figure 1.--Location of Diamond Lake.

DESIGN

The design team consisted of Roy Arnoldt, Geotechnical Engineer; Robert Nixon, Project Engineer; and John Rosenberger, Landscape Architect.

The design considerations for the new ramp were to:

(1) Provide protection for launching from waves generated by prevailing winds. Diamond Lake has five ramps, none of which has protection.

(2) Provide a facility with minimal annual maintenance.

(3) Provide a facility that is resistant to damage during the spring ice breakup.

(4) Minimize turbidity in surrounding lake water during construction.

(5) Provide 4-foot-deep water in the ramp area.

(6) Provide for handicapped access.

The design options considered are listed in table 1.

Table 1.--Design Option Considerations

Design options	Permanent	Ice resistant	Sides suitable for docking or mooring boats	Comments
Piled riprap	Yes	Yes	No	
Metal bin wall	Yes	Yes	Yes	Poor esthetically, with galvanized face
Gabions	Yes	Somewhat	With cast face	
Geotextile/ wire wall	Yes	Somewhat	With cast face	
Welded wire wall (Hilfiker)	Yes	Somewhat	With cast face	
Concrete crib	Yes	Somewhat	Yes	
Driven sheetpile	Yes	Yes	Yes	High cost of materials, rocky lake bottom may make driving impossible
Doublewall	Yes	Yes, if special design	Yes	Most acceptable appearance

The final design consisted of a jetty and ramp. The jetty was designed to provide a calm water launching site with a fetch (wind direction) of N 028 E. Class IX riprap with a 12-foot top and 2 feet of freeboard sloped 3:1 on the lake side and 2:1 on the ramp side was used. Doublewall bins were used to form the mooring/loading docks (figure 2). A special backfill design required that part of the fill be waterproof concrete to resist the freezing and ice pressure anticipated at the lake surface. The launching ramp was cast-in-place concrete.

Figure 2.--Setting doublewall units.

A solar-powered warning light like that used by the Coast Guard and Corps of Engineers for river navigation lighting was installed at the end of the jetty to warn nighttime lake traffic of the structure.

CONSTRUCTION

After contract award, three changes were made:

(1) Eight precast 7-foot by 18-foot slabs, set on a steel frame, replaced the cast-in-place slab. This reduced the amount of underwater construction and pumping because dewatering was not needed to place the slabs and sides.

(2) The cofferdam was deleted and a geotextile silt fence substituted to retain turbid water within the construction area. The geotextile barrier consisted of two layers of Mirafi 500X fabric supported by rope along a log boom and existing floating dock sections (figure 3). It was held to the lake bottom with rocks. The water behind the silt fence was 37 times more turbid from the construction activity than the adjacent open water (56 Nethlometric Turbidity Unit versus 1.5 Nethlometric Turbidity Unit). This containment of the turbidity proved very acceptable. These values remained typical except during periods of high northwest winds. This change resulted in a savings of $24,000.

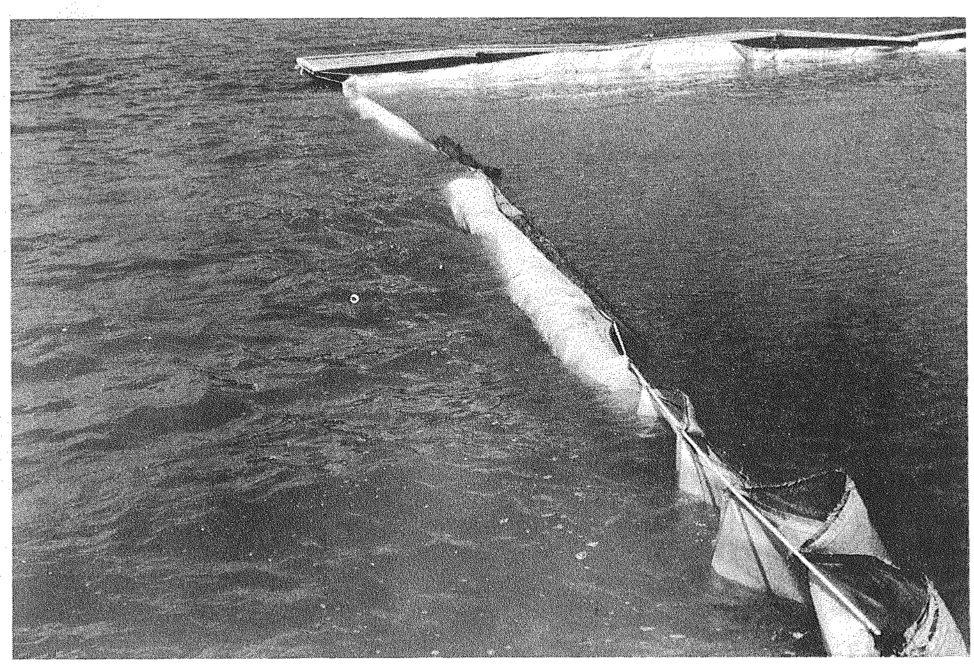

Figure 3.--Geotextile filter barrier.

(3) A concrete cap/walkway was added to the jetty to maintain the desired freeboard with the seasonal changes in lake elevation. The walkway also improved handicapped access and will allow for increased recreational use on the jetty.

The old and new ramps are shown in figure 4. The completed project cost $135,809. A new adjacent parking lot was constructed in the summer of 1987.

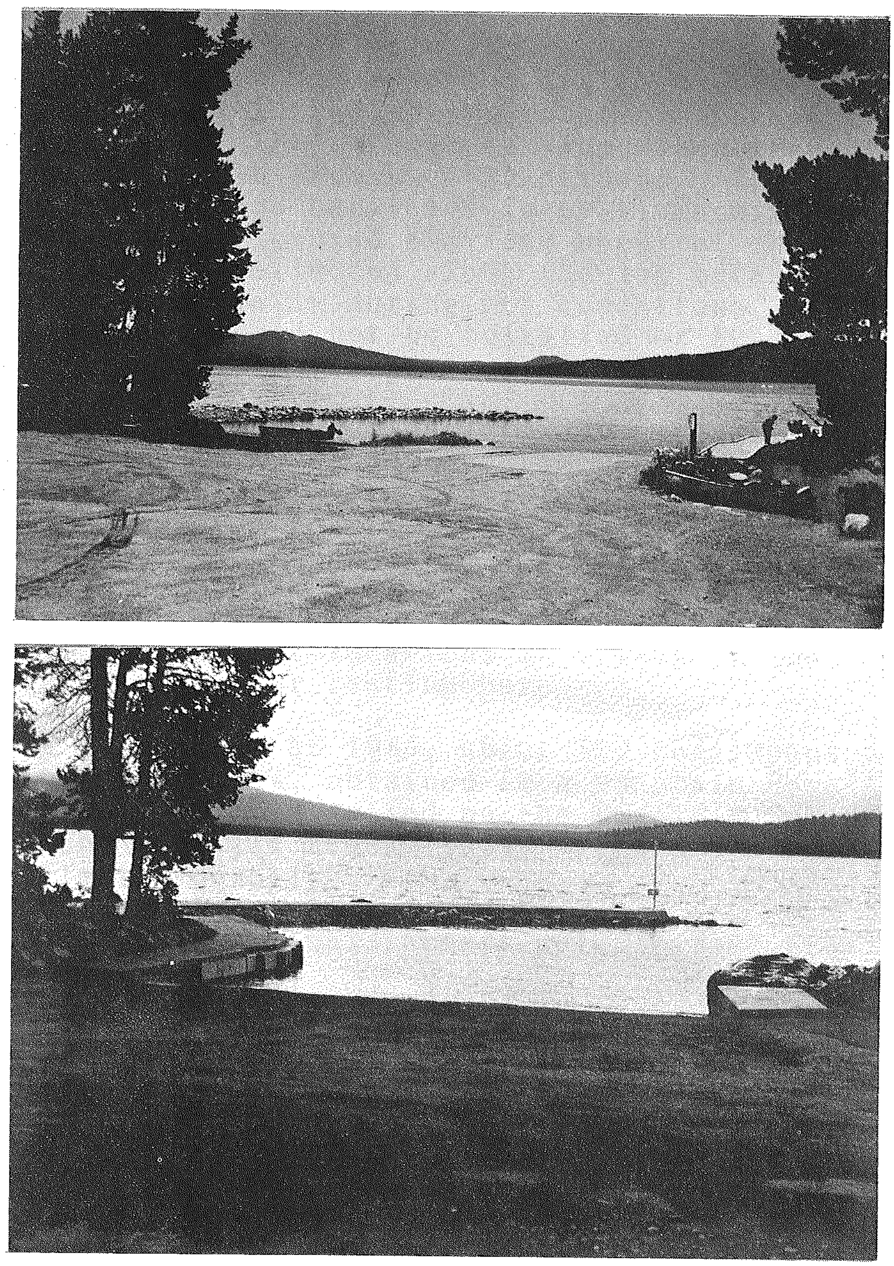

Figure 4.--Old and new ramps.

Continuous Belting Trail Drainage Structures

L.T. Kocmick
Transportation Engineer
Sawtooth National Forest, Region 4

The Sawtooth National Forest was dissatisfied with present designs for diverting surface drainage off of ORV (trail machine) trails, especially on older existing trails. The open-top drainage structures plugged; this required more maintenance funds than were available. The structures also did not function well on grades in excess of 10 percent. The round log waterbars were hazardous to trail machine riders because the logs caused the rear wheel of the trail machines to be deflected along the log because of the skew, especially during wet conditions. And drainage dips could not be installed or function on grades greater than 10 percent on existing trails.

Don Farrell, Helena National Forest, suggested using continuous belting, sandwiched between treated 2-foot by 6-foot timbers and buried in local roads to divert surface runoff. In 1984, the Forest fabricated a limited number of continuous belting drainage structures from conveyor belting and treated 2 by 6 timbers (figure 1). These were installed at select locations on trails in the Cassia Division for testing purposes.

During the summer of 1986, about 350 continuous belting structures, obtained from Mountain Home Air Force Base, were installed on the Virginia Gulch trail and the Calf Creek trail. Figure 2 shows installation details.

The following critical factors were learned from the test locations:

(1) The skew angle should be at least 45 degrees.

(2) The structure needs to be long enough to allow burying in the cut bank of the trail and extend beyond the shoulder of the trail, considering the angle of the skew.

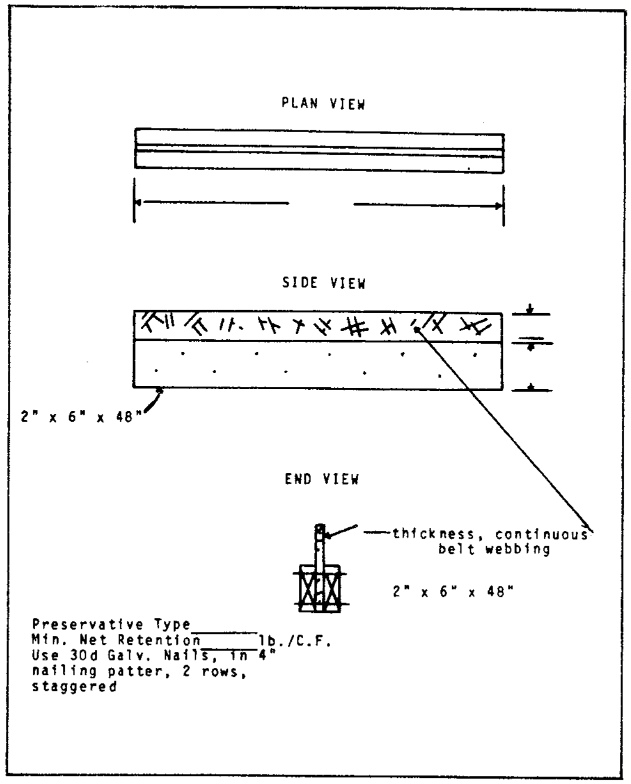

Figure 1.--Fabrication of continuous belting trail drainage structure.

(3) Continuous belting should protrude above ground no more than $2\frac{1}{2}$ to $3\frac{1}{2}$ inches since some belting material may develop a slight "memory" at the location where traffic passes over it and become floppy on high-use trails. A $2\frac{1}{2}$-inch extension above ground is recommended for high-use trails.

(4) The belting should be at least $\frac{1}{4}$-inch thick.

(5) Transportation of prefabricated units to the installation sites can be a problem because of the weight of treated timbers. Should this be a major problem, a number of alternatives are available for fabrication at the site using native materials--recognizing that the life of native material is less than that of treated timbers. See figure 3. The log can be slabbed or split with a chain saw at the site, and then the belting is placed between the pieces and nailed. Installation would be similar to that shown in figure 2.

This is a simple approach to an old problem on steep existing trails. It uses less material than the open-top drain and is easier to maintain in that one or two passes with a Cordic or shovel can clean the structure. The structure is inexpensive and has a safety advantage over existing designs for use on steep ORV trails.

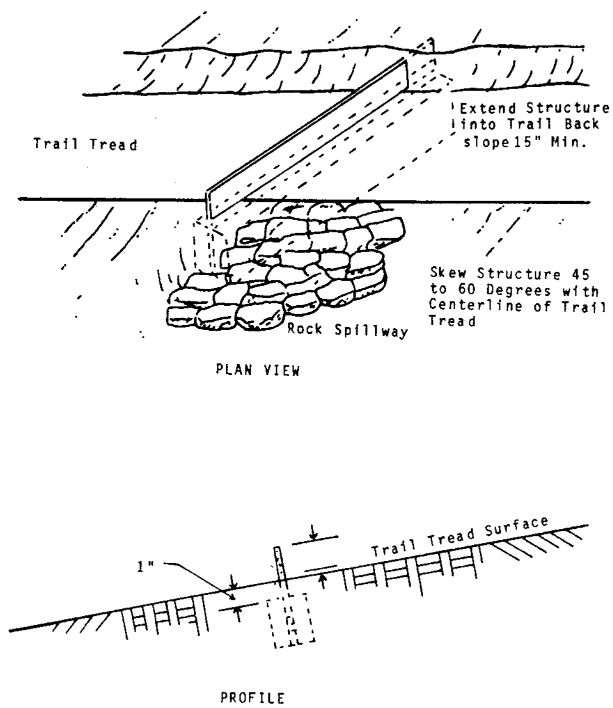

Figure 2.--Installation details.

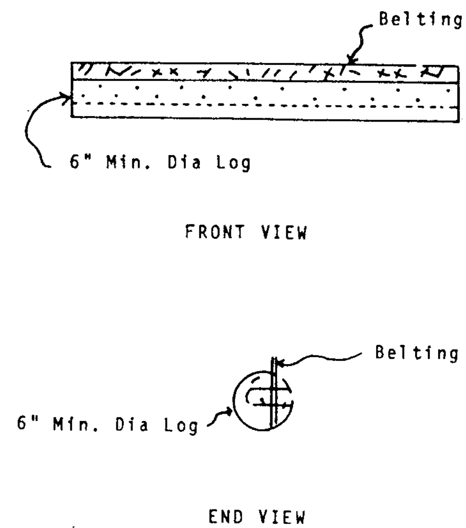

Figure 3.--Fabrication at the site using native materials.

Adrian Pelzner Receives ASTM Award of Merit

Adrian Pelzner (left) receives Award of Merit from ASTM Chairman of the Board, Robert Baboian.

Adrian Pelzner, former Forest Service Chief Geotechnical Engineer, was named a 1987 recipient of the American Society for Testing and Materials (ASTM) Award of Merit.

Pelzner, of Reston, Virginia, was presented the Award on June 22 in Cincinnati, Ohio, by ASTM Chairman of the Board Robert Baboian. The Award was sponsored by ASTM Committee D-18 on Soil & Rock, to which Pelzner has given 25 years of exceptional service.

Accompanying the ASTM Award of Merit is the honorary title of "Fellow of the Society." ASTM established both the award and the honorary title in 1949 to provide a means for recognizing productive service to ASTM, marked leadership, outstanding contribution, or publication of papers.

Over Pelzner's 25 years of service to ASTM Committee D-18, he has served both as Chairman (4 years) and Vice-Chairman (5 years); he also served 5 years as Chairman of the Subcommittee on Information Retrieval and 1 year as Chairman of the Subcommittee on Research & Standards Development. He also has served actively on several of ASTM D-18's technical subcommittees as well as on ASTM's Committee C-9 on Concrete & Concrete Aggregates, D-19 on Water, and D-34 on Waste Disposal.

Since his 1985 retirement, Pelzner has established a consulting research engineering practice in geotechnical engineering. In addition to remaining an active member in ASTM, Pelzner is a member of the American Society of State Highway & Transportation Officials, the Transportation Research Board, and the National Research Council's Commission on Engineering & Technical Systems.

EFN

Having worked for Adrian as Clerk-Typist in 1981 and 1982, I was very pleased to receive the notice of his Award of Merit. My admiration and sincere congratulations (and, I'm sure, that of countless others across the Forest Service) go to Adrian on this occasion.

--Editor

Multiple Resources Historic Evaluation—Lookout Tower Study, Pacific Southwest Region

John Grosvenor
Facilities O&M Staff Engineer
Regional Office, Region 5

BACKGROUND/NEED

As lookout towers move away from a primary fire detection role, they are being considered excess to Forest Service fire management. Alternative roles for historically significant lookouts, such as interpretive sites, adaptive use, or other continuing use as well as destruction or disposal, need to be examined.

Region 5 decided to develop a Programmatic Agreement with the State Historic Preservation Officer (SHPO) and the Advisory Council on Historic Preservation (ACHP). Invariably, when buildings are evaluated in isolation, they are often considered to be "significant," even though there may be a better representative sample of lookouts already being protected. The Programmatic Agreement will reduce the time, cost, and extent of consultation and provide a framework for making management decisions.

The thematic evaluation and nomination will enable the Region to protect a representative sample of significant lookouts and to focus its limited interpretation and restoration dollars on the most significant resources. The Region has 181 lookouts located on 19 National Forests scattered throughout California. Figure 1 contains photographs of five of these lookouts.

PROCESS/ REGIONAL OFFICE COORDINATION

The Region was fortunate to have a volunteer who offered his services to inventory and assist in evaluating <u>all</u> the lookouts in the State. At the same time, an ad hoc committee in the Regional Office was formed to coordinate and assist in the evaluation. This group included staff personnel from Cultural Resources, Fire Management, Property Management, and Engineering.

During the inventory phase, the volunteer visited each lookout and reviewed property records on the National Forests, plans and specifications in the

Figure 1.--Photographs of five Region 5 lookout towers.

Regional Office, and Fire Management historic files. In March 1987, the volunteer's report was completed. The ad hoc committee and each of the National Forests reviewed and updated information on the lookouts and provided evaluation during April and May. In June, the proposed Programmatic Agreement was submitted to the SHPO and ACHP for action.

EVALUATION CRITERIA/ CATEGORIES

Eleven separate criteria were used to evaluate each lookout (figure 2):

(1) Design Integrity--plan, space, structure, style, modifications to original.

(2) Esthetics Integrity--workmanship, materials, no additions to original.

(3) Interior--original furnishings intact.

(4) Integrity of Location--original location, no modern intrusions.

(5) Integrity of Buildings--original out buildings intact, no additions.

(6) Setting--physical setting, view, beauty of surrounding area.

(7) Tower/Cab--special features, special items in original design.

(8) Tower Height--some additional points awarded for taller towers.

(9) Association--events, people, patterns of history, CCC, WPA, Aircraft Warning Service (WW II), and so forth.

(10) Rarity--number of like category structures surviving.

(11) Date of Construction.

Because of the large number of structures in the Region, five categories were established to better compare like designs. These included observation only, live-in observation, wood, steel, and enclosed towers. The existing condition of the lookouts was not used as a selection criterion.

RATINGS/ REGIONAL OFFICE INPUT/FIELD INPUT/FINDINGS

All lookouts were first rated with scores ranging from -6 to 31 points. The Regional Office ad hoc committee then reviewed the results and spot checked lookouts that rated very high or very low, together with several at the mean area, and established a breakpoint at which lookouts would be recommended for the National Register. These results then were sent out to the National Forest for review.

FIRE LOOKOUT RATING SHEET

Lookout Name: **District**

National Forest: **Evaluator:**

County: Date:

Quad: Elevation:

Legal: T._____ R._______ 1/4______1/4_____
Section _____

Ownership:

Architect: Plan No.:

Builder: CCC FS Other

Tower (include height):

Cab: ** POINTS **

1.	Integrity/Design:	1_______
2.	Integrity/Esthetics:	2_______
3.	Integrity/Interior:	3_______
4.	Integrity/Location:	4_______
5.	Integrity/Associated Equipment and Buildings	5_______
6.	Esthetics/Natural Setting	6_______
7a.	Special Features (Tower):	7a______
7b.	Special Features (Cab):	7b______
8a.	Height of Live-in Tower:	8a______
8b.	Height of Observation-Only Tower:	8b______
9.	Association:	9_______
10.	Surviving Number (rarity):	10______
11.	Date of Construction:	11______

Comments:

Figure 2.--Lookout tower rating sheet.

PROGRAMMATIC AGREEMENT NOMINATIONS

The next step is to draft a Programmatic Agreement with the State Historic Preservation Office (SHPO) and the Advisory Council on Historic Preservation that will outline management options, including mitigation and standardization procedures for the Region. This Programmatic Agreement will reduce the level of consultation and documentation associated with a property-by-property assessment (which costs between $2,000 and $5,000 per individual structure).

The last step will be to select those lookouts that qualify for a thematic nomination to the National Register of Historic Places. This nomination will be based on Regional criteria, but will not rule out possibilities for inclusion of lookouts of local/Forest importance. The Region will consult interested parties. The Region will submit nominations to SHPO for its review and comment prior to nomination to the Keeper of the National Register of Historic Places.

Fish Habitat Improvement Using Photovoltaic-Powered Lake Circulation and Aeration

Mark Shaw
Fisheries Biologist
Gifford Pinchot National Forest, Region 6

INTRODUCTION

Two high-use recreation and fishing lakes in the Wasatch-Cache National Forest would not overwinter fish because of low oxygen conditions under the ice. The lakes were similar in their basic physical and biological characteristics; both Marsh Lake and Tony Grove Lake had no year-round inflow/outflow and were natural lakes, enlarged by dams for use as irrigation reservoirs. They were stabilized at full capacity and no longer used for irrigation, had developed extensive shallow areas with profuse aquatic plant growth, and previously had been known to overwinter fish. The Utah Division of Wildlife Resources had identified both lakes as priorities for habitat improvement.

LAKE REHABILITATION

The technology of lake improvement-rehabilitation has been highly developed in the past 20 years. Two basic techniques--(1) aeration by pumping air or oxygen directly into the lake and (2) circulation or mixing of the entire lake volume--were considered applicable to these two lakes. Previous Wasatch-Cache experience with winter aeration on a small scale, plus data from an extensive circulation study in the Midwest, indicated a high probability of success in the problem lakes (1).

The main challenge to implementing these techniques was the lack of electrical power to operate a compressor or circulator. Three options were investigated: (1) AC powerlines, (2) diesel or propane power generators, and (3) photovoltaics. Economic and environmental factors indicated that photovoltaics was a viable and reliable long-term power source for aeration and circulation. A funding request was subsequently submitted and approved under the Federal Photovoltaic Utilization Program to develop and implement improvement projects on the two lakes.

Design & Construction

The design of the axial flow pump was based on the projected use of 10 hours of total run time per day to effectively circulate Marsh Lake. This was calculated for the use period of around May 15 to October 30.

The axial flow pump for Marsh Lake was designed by Jim Garton of Oklahoma State University. The basic design was modified to use a 24-volt DC motor. The axial flow pump is a horizontally mounted impeller attached to a vertical output gear reducer powered by a 24-volt DC motor. This assembly was mounted on a 4-foot square raft constructed of redwood and filled with styrofoam, as shown in figure 1. The raft was anchored at each corner using $\frac{3}{8}$-inch coated cable attached to two concrete anchors. The impeller sat 3 feet below the water surface and rotated counterclockwise, pushing the water in a downflow direction.

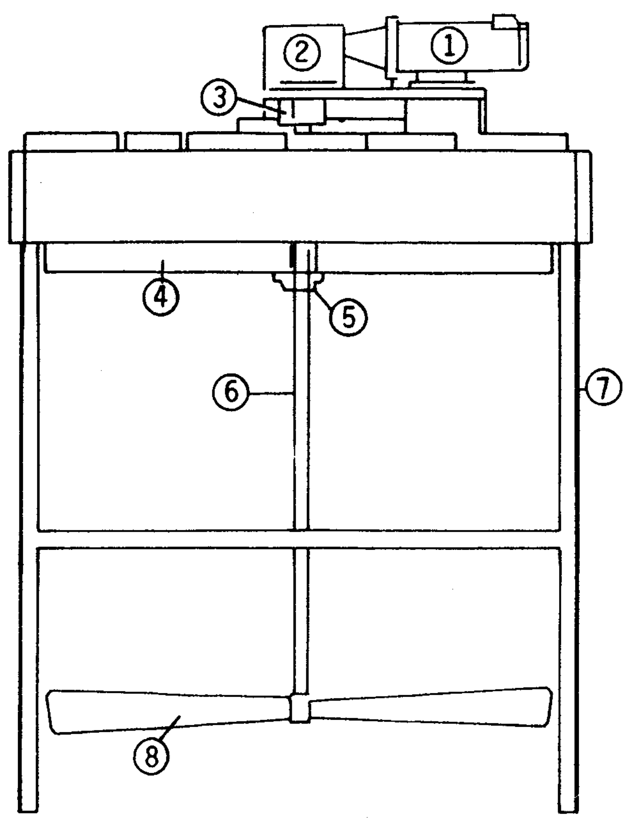

Figure 1.--Schematic of axial-flow pump used on Marsh Lake: (1) motor, (2) right-angle reduction gear, (3) chain coupler, (4) flotation, (5) bearing, (6) shaft, (7) frame, and (8) impeller.

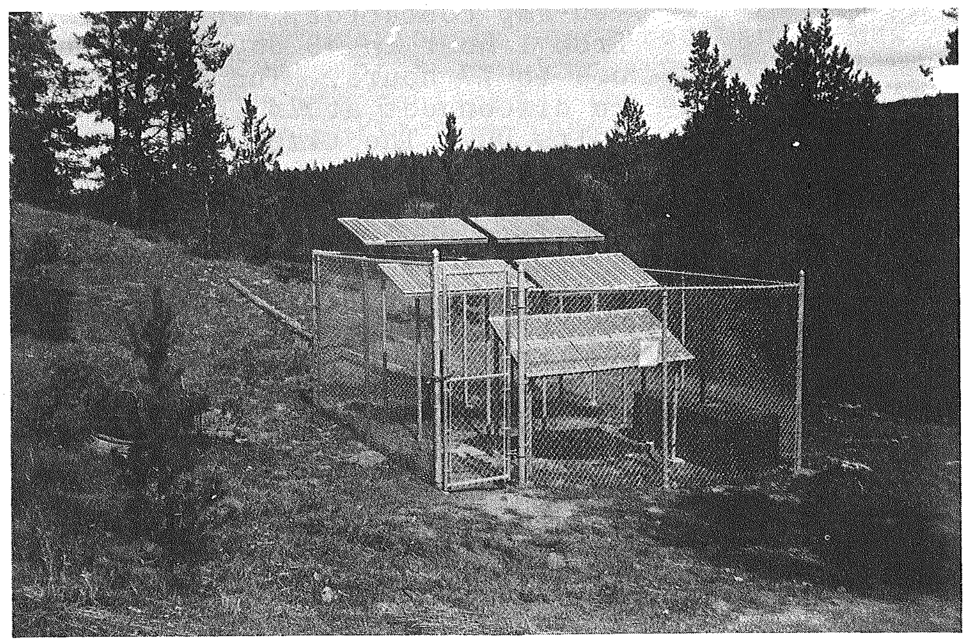

Figure 2.--Photovoltaic array and battery box at Marsh Lake.

The axial flow pump was designed with a ½-hp, 1800-rpm, 24-volt DC motor, 40:1 right angle single output shaft gear reducer, and a 42-inch impeller. The pumping rate was 1.4 acre feet per hour. The projected run time was 10 hours per day, resulting in 14 acre feet pumped per day. Marsh Lake had a total volume of 280 acre feet, resulting in 5 percent of the total lake volume pumped per day.

The photovoltaic array consisted of 32 ARCO ASI-16-2000 panels rated at 20 watts and 16 Sensor Technology 11113-01REV panels rated at 9 watts. The total array output was 784 watts. The electric motor had a draw of 450 watts.

Storage batteries were C&D, LCPSA-19 cells rated at 2.2 volts and 2,100 amp hours. These batteries provide 2 days of sunless operation at 10 hours operation time per day. Figure 2 shows the completed installation. Battery charge was regulated by two ARCO UCC 30-amp change controllers. Maximum array output was 25 amps at 24 volts DC.

The system for controlling the operation of the pump used a combination of a low voltage disconnect and timing control, with first priority to the low voltage disconnect. These two controls activated a 100-amp contactor. The timer can vary the run time from 1 hour to 45 days and the off time from 1 minute to 17 hours. The low voltage disconnect was set to disconnect at 24 volts DC and reconnect at 27 volts DC. The timer could be disabled, but the low voltage sensor always had control. These controls were mounted to one of the array stand pipes in a separate enclosure. Power was transported from the batteries to the pump with "0000" UD aluminum cable. The voltage drop was 0.3 volts between battery and pump.

Commercially produced pole mounts for the solar panels were not available. The pole mounting structure was fabricated by the Weber Basin Job Corps Center (WBJCC) welding shop. Four separate aluminum I-beam structures for eight ARCO panels each and one complete angle iron structure for the Solar Technology panels were constructed. These structures were mounted on a 2-inch steel pipe with variable angle tilt capacity. The axial flow pump was also constructed at the WBJCC.

Construction of the array began in July 1984. The major portion of the project took 8 days to complete. The work was done by a Forest Service work crew and members of the WBJCC welding shop.

Operating Experience

The system was not fully operational until the early fall of 1984 because the first control system, which included only a timer, did not arrive until late September. Total run time in 1984 was about 10 days. There was no noticeable effect on the oxygen content of the lake during the winter of 1984-85, and a complete winter fish kill was experienced.

The system was back in operation in June 1985 and was not monitored again until August 1985. It was found to be inoperative because the gear reducer had lost its oil because of a seal failure, and the gears were stripped.

The oil seal failure was determined to have been caused by the high running temperature of the DC motor, which normally has a high operating temperature, but it seemed to be higher than normal. The probable causes were determined to be low voltage at the motor due to a poor electrical connection between motor and cable and low voltage from the batteries. Low voltage would cause the motor to draw more amperage, resulting in higher operating temperatures. To remedy the situation, a new control system, which combined the low voltage disconnect and timer as previously described, and a new power cable to the motor connectors were installed. The gear reducer was replaced. The system was not operational again until June 1986.

The lake oxygen level was monitored during the winter of 1985-86 and is shown in table 1. The oxygen levels degenerated over the winter months to very marginal levels by the April sampling date. The lake ice cover did not break up until mid-May, but the oxygen levels remained high enough to overwinter part of the fish population. Creel census data revealed many 2- and 3-pound trout taken from the lake.

The pump was activated again on June 27, 1986. The voltage drop between the battery and motor was determined to be 0.2 volts, and the motor seemed to be operating at a cooler temperature. The lake had a well-defined thermocline at 5 meters of depth and was anoxic below this depth.

The pump and lake were checked on July 24, 1986. The system was still operating, but the gear reducer had again lost a seal, so the system was turned off.

Table 1.--Winter dissolved oxygen levels, Marsh Lake, 1985-86.

Date Sampled	Depth (m)	Level Dissolved Oxygen (mg/l)
12/23/85	0.5	9.0
	1.0	8.2
	2.0	7.6
2/26/86	0.5	4.2
	1.0	4.0
	2.0	3.2
	3.0	1.8
4/10/86	0.5	2.0
	1.0	1.5
	2.0	1.0
	3.0	1.0

Table 2.--Oxygen/temperature profile, Marsh Lake, June/July 1986.

Depth (m)	Temp (°C)	Level Dissolved Oxygen (mg/l)
0.5	15.5/14.4	8.5/8.8
1.0	15.0/14.4	8.5/8.8
2.0	15.0/14.4	8.2/8.7
3.0	14.0/14.2	7.4/8.7
4.0	13.0/14.2	6.2/8.6
5.0	12.0/14.0	5.5/8.4
6.0	10.8/14.0	5.0/8.4
7.0	10.2/14.0	4.2/7.9
8.0	9.8/14.0	3.2/7.9
9.0	8.8/14.0	1.5/7.9
10.0	8.8/14.0	1.0/7.9
11.0	8.8/14.0	1.0/6.2

The oxygen level of the lake was monitored at that time and is compared to the June levels in table 2. The lake had been mixed well by the axial flow pump. The temperature difference between the surface and bottom was 0.4 °C, and the dissolved oxygen difference between surface and bottom was 2.6 milligrams per liter. There was still a measurable amount of oxygen being consumed at the water-sediment interface, but this is the exact phenomenon the pump was intended to create. The oxygen/temperature profile was not taken again during the summer of 1986. The oxygen levels of the lake were monitored during the winter of 1986-87.

To alleviate the problem of the high operating temperatures and subsequent gear reducer failure, a new motor and gear reducer were installed on the pump during October 1986. A larger 3/4-hp, 24-volt DC motor was installed on a new and larger gear reducer. A ventilation cap was also installed above the motor/gear reducer to facilitate air circulation. The larger motor will be operating below its maximum designed output and consequently should operate within the normal operating temperatures of the gear reducer.

Conclusion

Although the axial flow pump has been plagued with problems during its relatively short periods of sustained operation of 1 to $1\frac{1}{2}$ months, it does seem to be thoroughly destratifying and mixing the lake. The results from the 1985-86 winter were very promising, and the brief mixing in the summer of 1986 is expected to produce better results in the 1986-87 winter. The new motor-gear reducer combination should alleviate breakdowns and result in a summer-long sustained circulation in 1987.

The solar array, batteries, control system, and power cable components have functioned well in this remote location. Maintenance on these components has been confined to battery maintenance and changing the solar array tilt angle. Although it is located next to a high-use campground, vandalism has not been a problem. This is probably because of its relatively isolated location and the 8-foot chain link fence enclosure. With the experience gained in proper control system design and axial flow pump design with DC motors, this system could be readily adapted to other remote locations with similar lake winterkill problems.

TONY GROVE LAKE SYSTEM

Design & Construction

The design, siting, and construction of the Tony Grove Lake system presented several challenges. The lake had a visual classification of retention, which means manmade activities cannot be seen, dictating that the photovoltaic array site be placed away from the lake. The aeration system would be composed of a compressor, airline, and air diffuser. The factors of airline pressure loss, depth of the lake, and diffuser material pressure loss all needed to be accounted for. The area also had very deep snow depths of 8 feet and over.

The challenge then was to design an effective aeration system that could meet the visual and environmental constraints and still stay within budget. A suitable site, 1,400 feet northwest of the lake, was located. It offered relatively easy foot access and was visually isolated from the majority of area users.

The photovoltaic array was composed of 25 Solavolt 37-watt modules. Charge controllers included one 12-volt DC ARCO UCC and two 12-volt DC Solarwest

Electric units. The battery bank was composed of 12 Willard (Exide) DH5-1 cells in 12-volt DC array. The load control system included a low voltage disconnect and timer combination, with first priority to the disconnect system.

The compressor system was originally composed of two 12-volt DC diaphragm pumps, with a combined power draw of 180 watts and air delivery of 0.7 cubic feet per minute at 25 psi. These were later replaced by a single 12-volt DC twin piston compressor with a power draw of 20 watts and air delivery of 1.5 cubic feet per minute at 25 psi. The average array output was 3,800 watts per day, for a maximum pumping time of approximately 17 hours per day.

The photovoltaic array was broken into three separate units of 10, 10, and 5 panels each. They were each mounted on 4-inch pipes, spaced 9 feet apart to prevent shading. The mounting structures had a variable angle capability, and the panels were to be set at 20 degrees in the summer and 60 degrees in the winter.

The batteries and electronic controls were mounted in an enclosure constructed of 2-inch by 8-inch redwood, sealed with silicon caulking, and vented with a 2-inch by 10-foot plastic pipe. The solar panels were mounted on 4-inch diameter by 12-foot long galvanized steel pipes. The three banks were composed of 10, 10, and 5 panels each. The compressor was mounted in a vented metal enclosure attached to the pole mount structure of the 5 panel bank. A flexible rubber hose enclosed in a rigid plastic pipe delivered air from the compressor to the ½-inch polyethylene air delivery pipe.

The entire assembly was enclosed in an 8-foot high chain link fence to reduce the possibility of vandalism and theft. Figure 3 shows the completed installation.

The air delivery system was composed of ½-inch black polyethylene pipe, buried 8 inches deep. The diffuser system was designed with two separate units. The first was a 2-foot long by 1-inch diameter diffuser made of porous high-density polyethylene with a pore size of 15 to 30 microns. Its primary purpose was to lift water from the bottom to the top of the lake, causing a mixing effect during the months of June through October. The second diffuser was composed of three ceramic heads with a

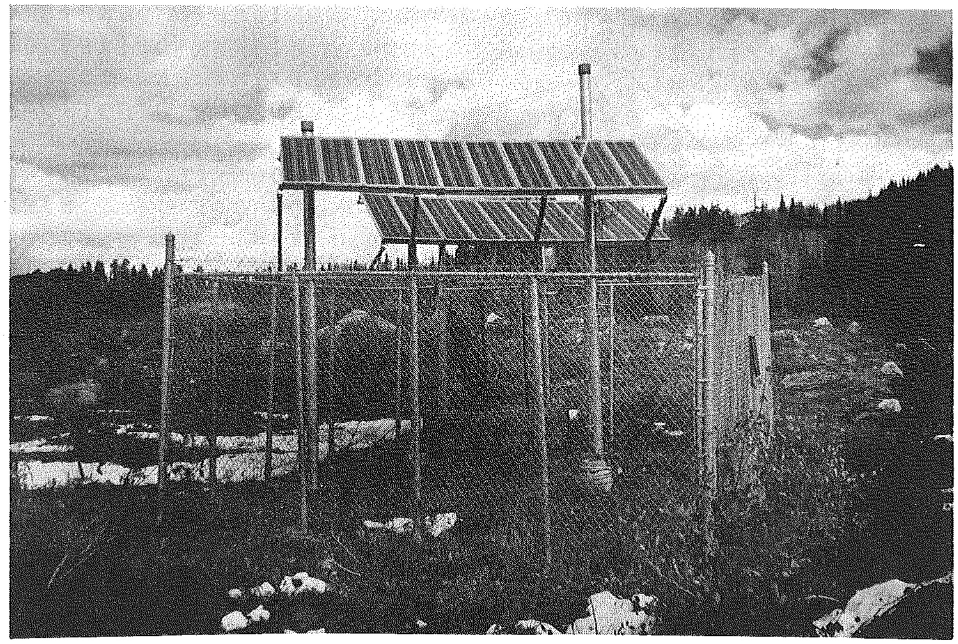

Figure 3.--Tony Grove Lake solar array, battery and control box, and compressor box.

pore size of 3 microns. Its primary purpose was diffusion of air into the water to increase the dissolved oxygen content during the ice-covered months of November through May. The aeration system is conceptually shown in figure 4.

Construction of the facility began in August 1984 and was completed in approximately 7 days. All work was done by a Forest Service crew consisting of three to seven people. All transportation of materials from the highway to the work site was done by pack horse or humans. All other phases of the work were completed by handpower, except for the air delivery line, which was dug using a gas-powered trencher.

The major obstacle encountered in construction was placing the mounting poles for the solar panels. Large rocks encountered while digging the pipe holes prevented the poles from being placed in their exact predesigned locations and depths within the fenced enclosure.

Operating Experience

The system was put into operation in September 1984. The initial problem encountered was a block in the air delivery line. The blockage location was

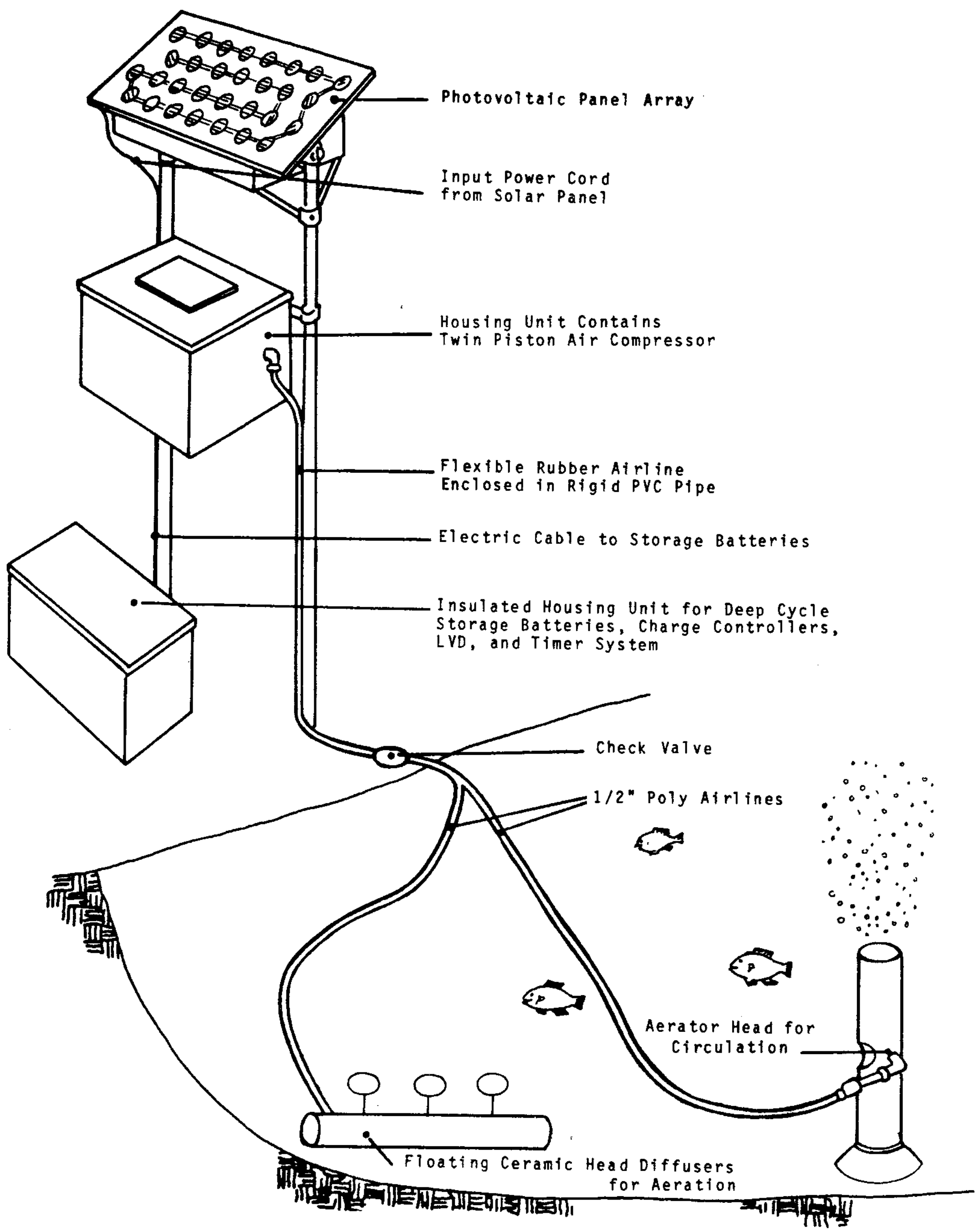

Figure 4.--Solar-powered lake aerator at Tony Grove lake.

located in the lake in late September. The system then was operational until May 1985. At that time, one of the diaphragm pumps malfunctioned. The one remaining diaphragm pump was put back into service, but failed within 1 week. A new twin piston compressor was installed in September 1985 and has functioned successfully ever since.

The original load control system proved to be inadequate. It was not capable of handling the high amperage loads at 12 volts DC. It was replaced with a load control system comprised of a low voltage disconnect and timer, which activated a 100-amp contractor completely separate from the disconnect and timer. These have functioned well since their installation.

Normal snow depths in the area are up to 7- to 8-feet deep. During the first winter of operation, 1984-85, some damage occurred to the chain link fence, which was slightly reinforced in the summer of 1985. The winter of 1985-86 brought snow depths of more than 14 feet. The system had not been designed to take such snow loads, and the entire assembly was buried under snow by February 1986.

After spring snow melt, the fence and pole mounting structures looked like pretzels, but amazingly, the system was still running. No wires were broken, and only superficial damage occurred to the panels. The fence and mounting structures were repaired in July 1986. The fence was reinforced, and the pole mounting structures were all reconstructed. In the future, if snow cover approaches critical depths, the arrays will either be placed in a vertical mode so they carry no snow load, or the mounting pipes will be extended to accommodate the deeper snow depths.

Effects on the Lake

Winter Effects. During the first winter of operation in 1984-85, there was no measurable increase in the dissolved oxygen content of the lake. The last measurements taken in mid-April indicated the highest dissolved oxygen concentration was 2.5 milligrams per liter at 0.3 meters of depth. During the second winter of operation, 1985-86, the last measurement was taken on February 4, 1986. At that time, dissolved oxygen content was measurably higher than in previous years. These data are presented in table 3.

Table 3.--Oxygen/temperature profile, Tony Grove Lake, February 4, 1986.

Depth (m)	Level Dissolved Oxygen (mg/l)	Temp (°C)	pH
0.5	5.0	2.0	
1.0	3.5	2.0	
2.0	3.0	2.0	7.2
3.0	2.8	2.0	(Note: pH
4.0	2.8	2.0	readings were
5.0	2.5	2.0	taken only at
6.0	0.8	2.0	the 2 m depth)

The lake had enough oxygen in the first 4 meters of depth to sustain fish life. The temperature was relatively homothermic and colder than normal in the first 6 meters. This was caused by the open hole, which permitted the lake to radiate heat into the colder surrounding air. The lake was not measured after this date because, as the snow depths increased, the panels were buried and the compressor was shut down. The lake refroze and snow depths became too deep to sample the lake.

Hikers to the lake in the early spring said they saw large numbers of fish downstream of the outlet works, indicating they overwintered in the lake and moved out with the spring snowmelt.

Summer Effects. There was no effect during the first summer because of the short time of operation. This pattern was repeated in 1985 due to the failure of the pumps. The first full summer of operation took place in 1986. The data in table 4 show the effects of the aerator.

These data were collected between the aerator heads. Data collection was repeated at locations 200 feet north and south of the aerator heads. The lake was nearly homothermic, with a 6 °F difference between the surface and bottom. No distinct thermocline could be found in the lake.

The dissolved oxygen content also correlated with the temperature profile, remaining relatively high until the last meter of depth. This indicates that there was still a high oxygen demand in the bottom sediments, which extends upwards into the water column to a depth of 4 to 5 meters. The mixing effect of the diffuser heads was not as efficient as the axial flow pump design, but it has prevented the lake from becoming thermally stratified. The increased dissolved oxygen content in the lower depths should decrease the dissolved oxygen demand during the ice-covered months.

Conclusion

The aerator/circulator system on Tony Grove Lake seems to be having a positive effect on the dissolved oxygen content during the ice-covered months. The system has yet to be operational for a full summer circulation/winter aeration cycle. This should occur during the summer/winter of 1986-87. The load control and compressor systems are now functioning well, and barring another year of record snow depths, the aerator will function throughout the winter. Measurements will be taken during the winter of 1987 to further evaluate the effects of winter aeration on the lake.

Table 4.--Oxygen/temperature profile, Tony Grove Lake, August 26, 1986.

Depth (m)	Level Dissolved Oxygen (mg/l)	Temp (°F)
Surface	10.9	62.0
0.5	10.2	62.0
1.0	10.5	62.0
2.0	10.4	62.0
3.0	10.4	62.0
4.0	8.8	62.0
5.0	8.2	60.0
6.0	6.5	59.5
7.0	6.8	59.0
8.0	6.5	58.0
9.0	1.1	56.0

REFERENCE

1. Summerfelt, R.C. and T.K. Cross. Artificial Destratification to Prevent Winterkill. Iowa State Water Resources Research Institute, Ames, Iowa (1983).

Mark Shaw wrote this article while on the Wasatch-Cache National Forest. He transferred to the Gifford Pinchot National Forest last June.

He advised me in August that both systems are working the way they were designed to work, although there was still a fish kill during the winter of 1986-87. He expects this situation to improve gradually.

If you are interested in speaking to Mark, call him at FTS 422-7531 or DG him at M.SHAW:R06F03A.

--Editor

Airfield Expert System

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Civil Engineer
Systems Operations, Analysis, & Development
Washington Office

INTRODUCTION

The Forest Service has built and is maintaining more than 100 airfields across the country. One-fourth of these airfields are located in Region 4, which consists of Idaho, Utah, Nevada, and part of Wyoming. The Forest Service airfields, along with hundreds of municipal and private airfields, are the main transportation facilities for access to remote areas where the terrain prevents the construction and operation of ground transportation systems. The Forest Service shares the use of its facilities with other Federal agencies, State and local governments, private organizations, and individuals.

The major function of Forest Service airfields is to support fire suppression activities. Some airfields are also used for commercial purposes, such as transporting recreational travelers and supplies and delivering Postal Service mail to isolated ranges.

The airfields are called "back-country landing strips" or "wilderness landing strips," or sometimes simply "landing strips." Because of the constraints of geological conditions, including terrain, soil type, windspeed and direction, fog, and so forth, the configuration of a back-country strip differs from one location to another. For example, figure 1 shows a strip similar to an aircraft carrier runway. Figure 2 shows a Y-shaped runway (as opposed to an X-shaped); this serves as a major runway with a crosswind runway. Figure 3 exhibits two parallel runways on a strip. Some back country strips demand the highest degree of mountain flying skill and should only be attempted by pilots familiar with canyon and short field operations. The landing strip in figure 4 is 1,745 feet long, but there is a swamp at one end and a 30 percent grade downslope at the other end.

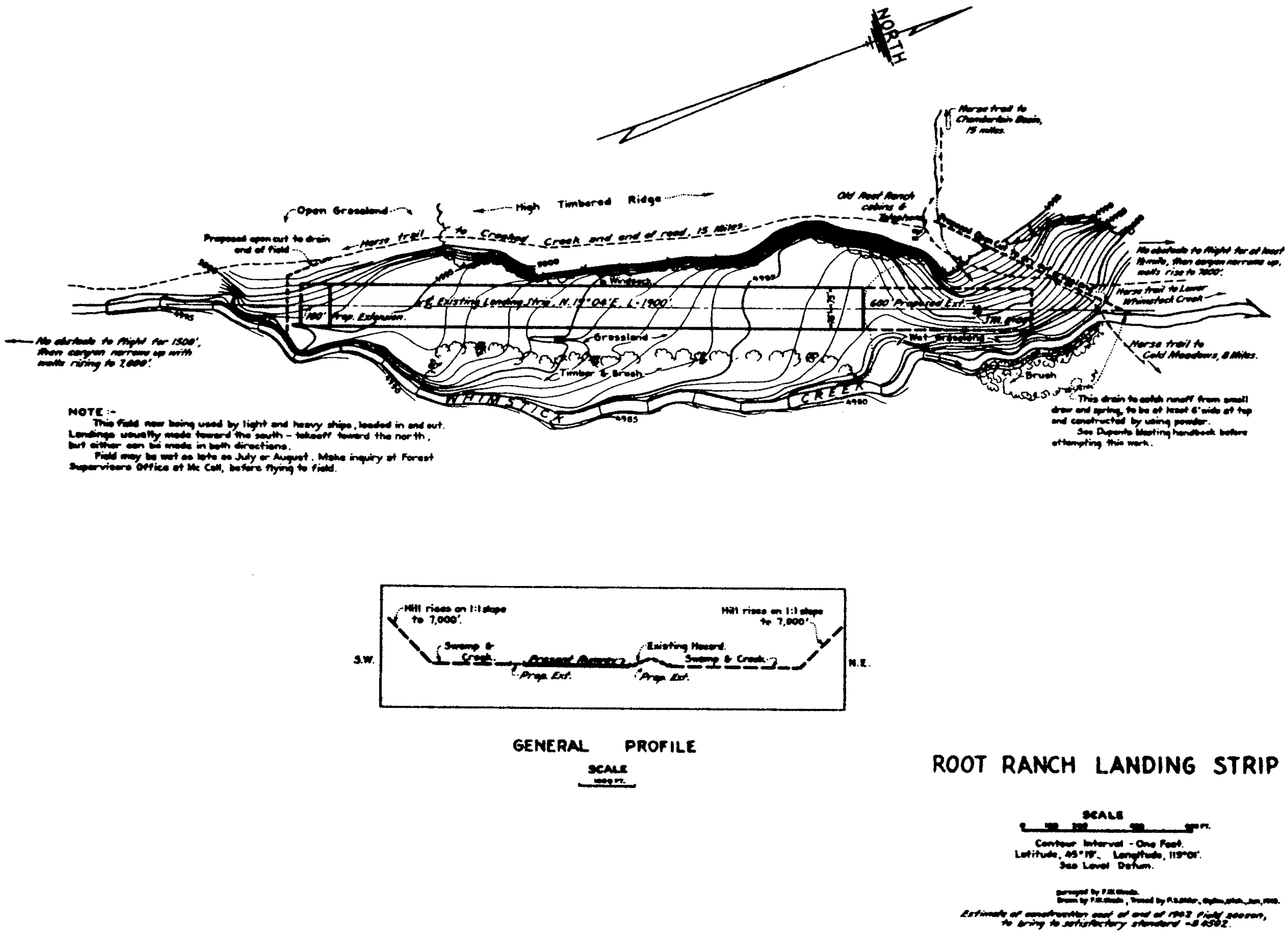

Figure 1.--Root Ranch landing strip.

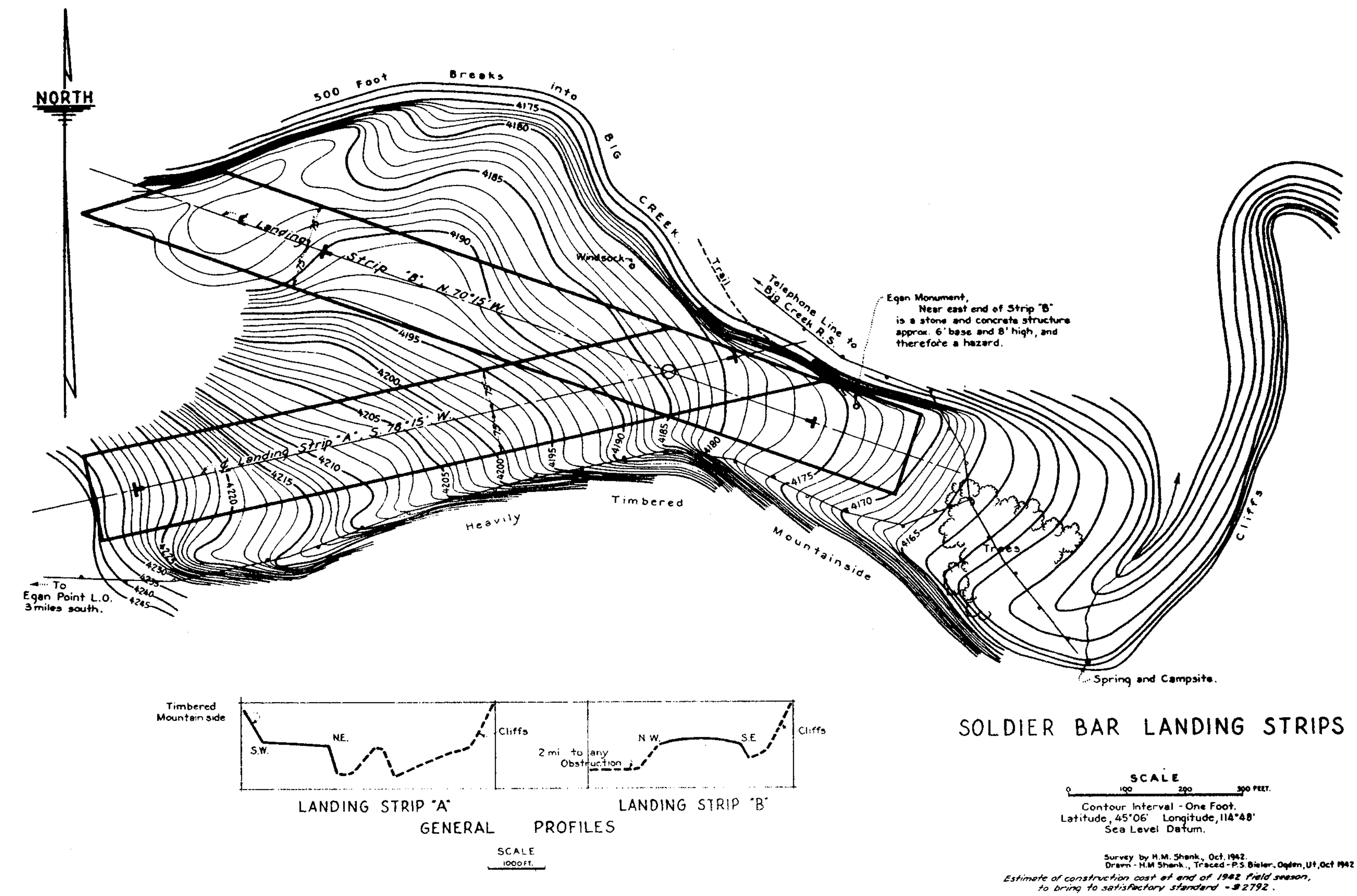

Figure 2.--Soldier Bar landing strips.

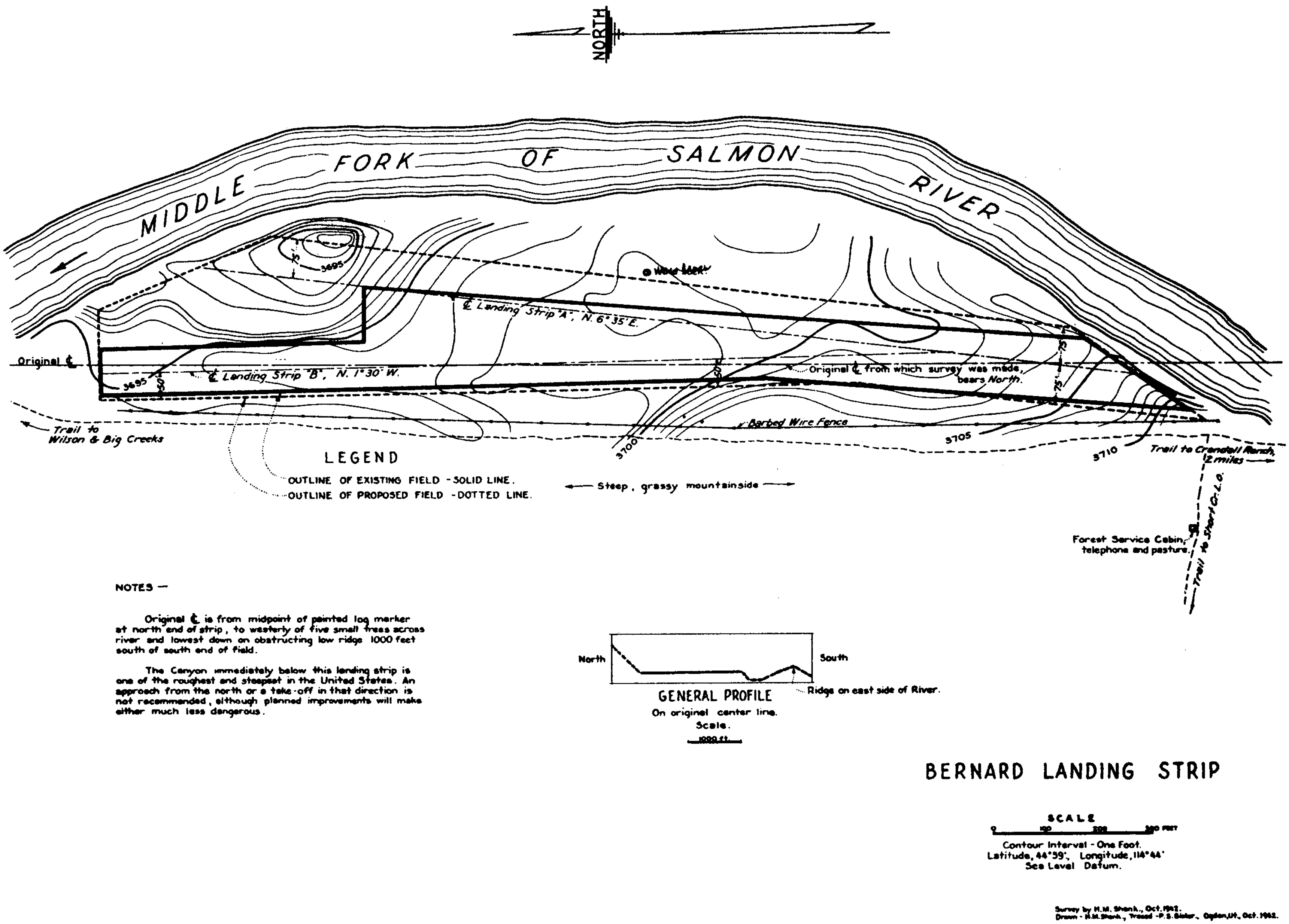

Figure 3.--Bernard landing strip.

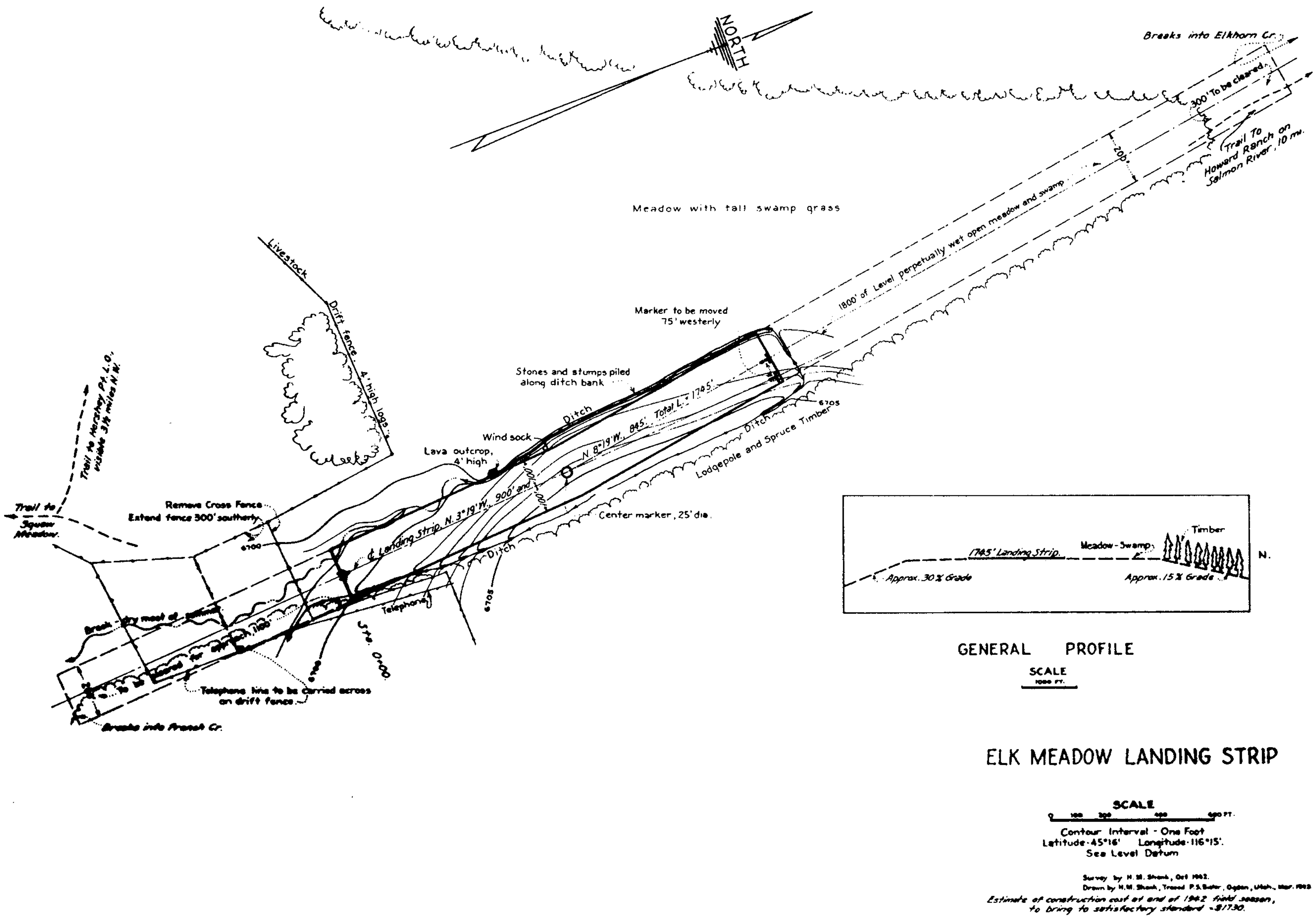

Figure 4.--Elk Meadow landing strip.

This article reports the development of a prototype expert system dealing with airfield design, operation, and maintenance. The purpose is to demonstrate that expert systems can be additional tools to aid engineers in solving engineering problems by using airfield design, operation, and maintenance as an example.

SOFTWARE SELECTION

Today, a large number of expert system shells have been developed for various computers and are currently on the market. EXSYS was selected for the application presented here because it is easy to learn and use and can run on our existing equipment, including IBM PC's and the AT&T 6300 PC.

SYSTEM DEVELOPMENT

The Airfield Expert System is designed to cover three major aspects--design, operation, and maintenance--and two types of airfields--back-country landing strips and higher standard airfields. The former type has turf surfacing and uses visual approaches for landing. The latter may have bituminous pavement runways with better facilities, such as control towers, lighting, and marking, and uses precision instrument landing approaches.

The data base was obtained from various sources, including pilots, facility management engineers, the FAA Advisory Circulars, and the Forest Service Manual (FSM). The airfield facilities are determined by aircraft characteristics and airfield environmental conditions. The aircraft characteristics consist of approach speed, wingspan, type of engine, size of aircraft, maximum takeoff weight, and ability to operate at the higher altitudes. The airfield environment includes altitude, temperature, wind speed and direction distribution, soil type, and drainage condition.

The three major functions of the system are as follows:

Design--This function includes seven design modules: (1) wind analysis; (2) runway length and landing strip size; (3) standards other than runway length; (4) site investigation; (5) airplane parking and tiedowns; (6) marking, lighting, and visual aids; and (7) airfield surfacing. In figure 5, Basic Utility Stage I is defined as a type of airfield serving approximately 75 percent of the single-engine and small twin-engine airplanes used for personal and business purposes. Basic Utility

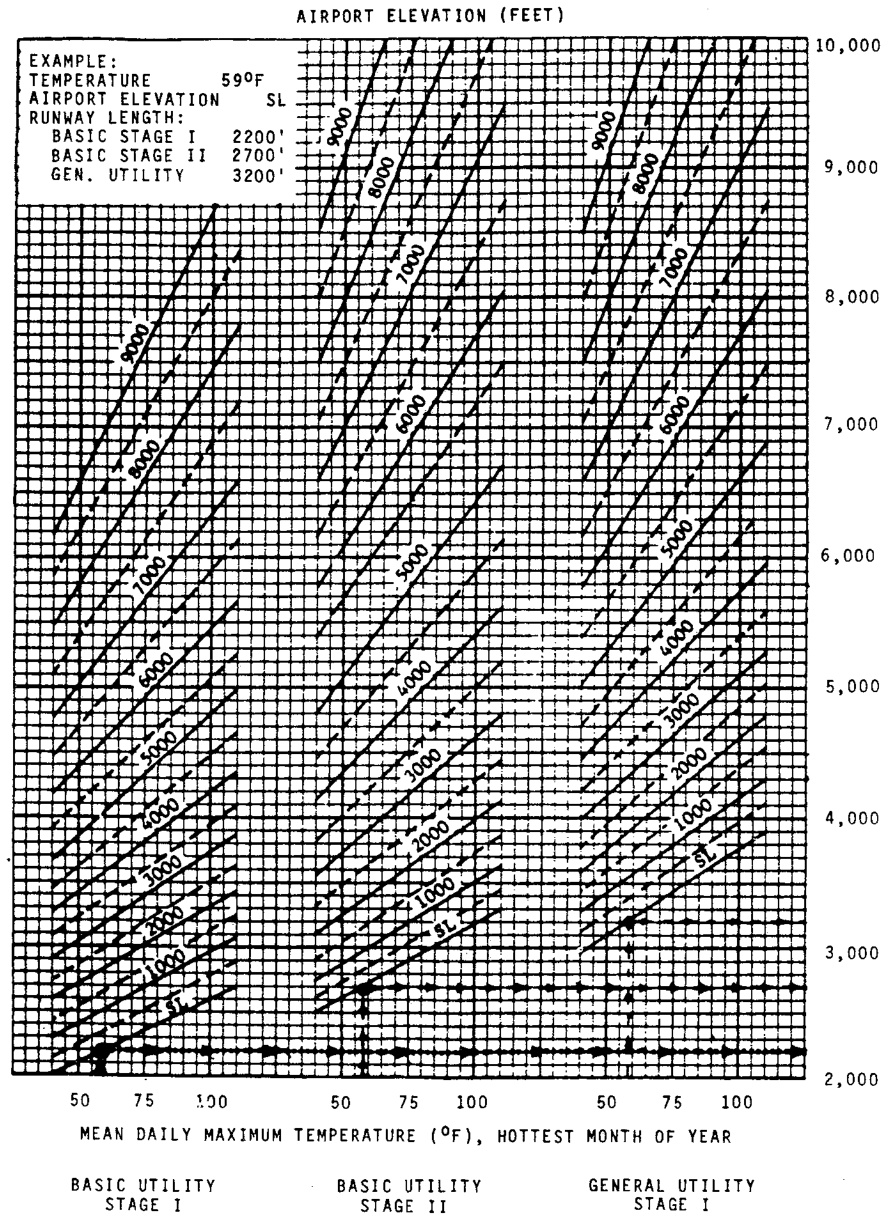

Figure 5.--Runway length curves (adopted from FAA AC 150/5300-4B).

Utility Stage II is the type of airfield that serves all the airplanes of Stage I, plus some small business and air taxi-type twin-engine airplanes. General Utility Stage I is the type of airfield serving all airplanes. Both runway length and depth of surfacing, in terms of pavement, aggregate, base, and subbase, require computation. For this purpose, figures 6 and 7 were transformed from family curves to formulas and incorporated in the system. Based

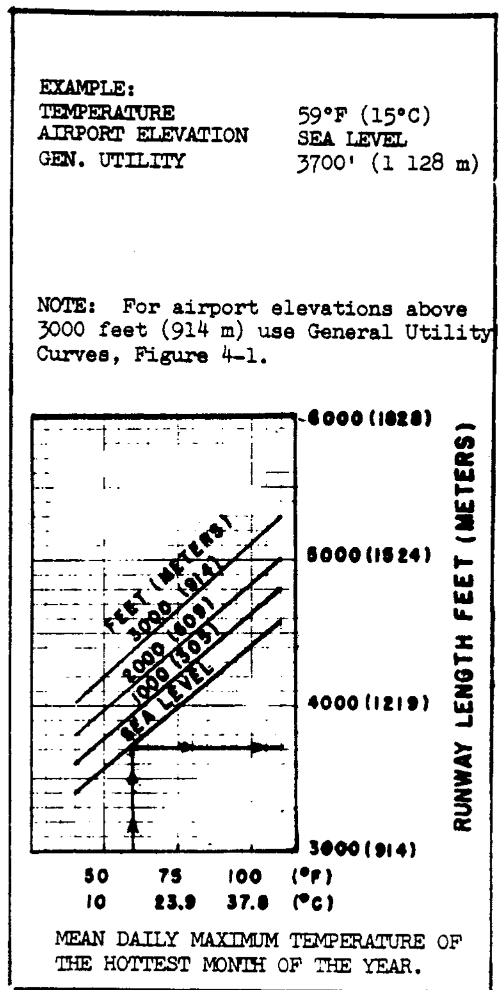

Figure 6.--Runway length to accommodate airplanes having a seating configuration of ten passenger seats or more (adopted from FAA AC 150/5300-4B).

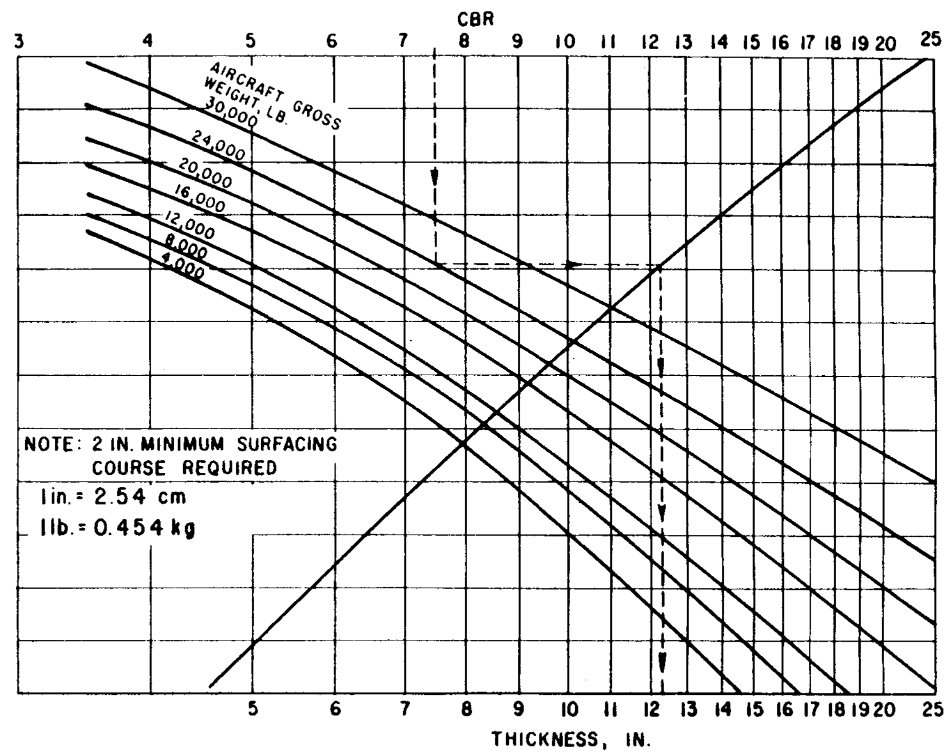

Figure 7.--Design curves for flexible pavements (adopted from FAA AC 150/5320-6C).

on the conditions of the airfield and its characteristics, the design function can be used to select cost-effective design standards.

Operation--This function provides airfield operation guidance based on the FSM 7700 Transportation System. It allows for the selection of aircraft type based on the existing runway length along with the airfield environmental conditions.

Maintenance--This function provides the minimum airfield maintenance standards and the requirement for the closure of airfields (temporarily, periodically, or permanently).

SYSTEM OPERATION

The following example shows how to use the Airfield Expert System to select a site in terms of the runway length and total area of the airfield.

Insert the RUNTIME disk in drive A (change the drive from B or C to A by typing "A:"), and type "exsys." The system will ask "Expert System file name:." Replace the RUNTIME disk with the AIRFIELD EXPERT

SYSTEM disk and type "airfield." The screen will display two questions:

```
Do you wish to have the rules displayed as they
are used? (Y/N)
  (Default=N)
Recover previously saved input? (Y/N)
(Default=N)
```

After the above two questions are answered, the title and author of the system will appear on the screen. Press any key, and the screen will show a beginning text. Then the system will begin to ask questions after any key is pressed.

```
Question:  The airfield that you are dealing with is
             1    a back country landing strip
             2    a high standard airfield

Select:    1
```

The following instruction appears on the bottom of the screen:

```
Enter number(s) of value(s), WHY for
information on the rule, <?> for more details,
QUIT to save data entered, or <H> for help
```

Before answering the question, the user can ask the system why the information is needed or for more details. For instance, if the user types "WHY," Rule 16 appears:

```
RULE NUMBER:  16
IF:
        (1)    The airfield that you are dealing
               with is a back country landing
               strip or a high standard airfield
and     (2)    The objective of airfield design is
               needed
and     (3)    The runway length and capacity is
               needed
and     (4)    The airfield type is Basic Utility
               Stage I
and     (5)    [AE] <= 1000

THEN:
               Runway length and capacity -
               Probability=1
and            [RUNWAY LENGTH] IS GIVEN THE VALUE
               (2000 + .3*[AE])+(((2600 + .35*[AE]
               -(2000 + .3*[AE])))*([TEM] -40)/60)
```

NOTE: Assumed conditions are (a) zero headwind, (b) maximum certificated takeoff and landing weights, (c) optimum flap setting for the shortest runway length (normal operation), and without consideration of other factors, such as relative humidity, runway gradient, takeoff under tailwind, etc. Where AE = airfield elevation, TEM = temperature.

IF line # for derivation, <K>-known data, <C>-choices, <R>-reference, or - prev. or next rule, <J>-jump, <H>-help or <ENTER> to continue:

The instruction for obtaining more information is given on the bottom of the screen.

Question: The objective of this action is
1 airfield design
2 existing airfield operation
3 existing airfield maintenance

Select: 1

Question: The selected module is
1 wind analysis and runway orientation
2 runway length and capacity
3 standards other than runway length
4 site investigation
5 airplane parking and tiedown
6 marking, lighting, and visual aids
7 airfield surfacing

Select: 2

Question: Please input the approach speed of aircraft in knots

Enter: 90

The following instruction for the response to the query appears on the bottom of the screen:

Input a value for the variable less than 121.000000 'WHY' for information, <?> for more details or 'QUIT' to save data:

Question: Please input the maximum certificated takeoff weight (lb)

Enter: 10000

Question: The airplane seating configuration is
1 less than 10 passenger seats
2 equal to or more than 10 passenger seats

Select: 1

Question: Small turbojet airplanes are
1 operated
2 not operated

Select: 2

Question: The airfield is designed to serve
1 about 75% of single-engine and small twin-engine airplanes used for personal and business purposes
2 95% of small airplanes including all the airplanes of choice #1, plus some small business and air taxi-type twin-engine airplanes
3 100% of small airplanes
4 only small airplanes with approach speeds less than 30 knots
5 only small airplanes with approach speeds equal to or more than 30 knots and less than 50 knots

Select: 2

Question: Please input the length of wingspan in ft

Enter: 35

Question: The runway type is
1 a precision instrument runway
2 a nonprecision and visual runway

Select: 2

Question: Please input the airfield elevation above mean sea level (ft)

Enter: 3000

Question: Please input the mean daily maximum temperature in Fahrenheit for the hottest month

Enter: 75

Question: The critical airplane that is not capable of operating at high altitude without modification is
1 expected
2 not expected

Select: 2

Question: A crosswind runway is
1 needed
2 not needed

Select: 2

Question: The adjustment of tailwind factor is
1 needed
2 not needed

Select: 1

Question: The adjustment of gradient factor is
1 needed
2 not needed

Select: 1

Question: Please input the tailwind speed in knots

Enter: 3

Question: Please input the effective runway gradient in percent (%)

Enter: 2

After the end of query, an ending text as shown below appears:

> When you press any key the results will be displayed. The selected standards can be used for planning new airfields or used for operation and maintenance of existing airfields.
>
> Press any key to display results:

The results are shown below:

	Values based on 0/1 system	VALUE
1	Runway length and capacity	1
2	The minimum requirement for approach area is 21 acres	1

3 the airfield elevation above mean sea level (ft) = 3000
4 the length of runway in ft = 4166.666667
5 the approach speed of aircraft in knots = 90
6 the length of wingspan in ft = 35
7 the mean daily maximum temperature in Fahrenheit for the hottest month = 75
8 the tailwind speed in knots = 3
9 the effective runway gradient in % = 2
10 the runway length adjusted by both tailwind factor and effective gradient factor = 5953.333333
11 the minimum requirement for landing area (acres) = 42
12 the minimum requirement for the total area of airfield (acres) = 63
13 the maximum certificated takeoff weight (lb) = 10000

When the value = 1, it means that the item is selected; otherwise, the value = 0, or none.

The following are options to deal with the results:

All choices <A>, only if value >1 <G>, Print <P>, Change and rerun <C>, rules used <line number>, Quit/save <Q>, Help <H>, Done <D>:

If the user wants to use the system to compare the design standards of two sites with different elevations and temperatures, he or she should select "C" for change and rerun. The system will ask:

Do you wish to store the current results for comparison with the new results you will be calculating? (Y/N) (Default=Y):

After answering the above question, a list of data appears as follows:

1 The runway type is a nonprecision and visual runway
2 The airfield is designed to serve 95% of small airplanes including all the airplanes of choice #1, plus some small business and air taxi-type twin-engine airplanes
3 The airplane seating configuration is less than 10 passenger seats
4 Small turbojet airplanes are not operated
5 A crosswind runway is not needed
6 The adjustment of tailwind factor is needed

```
7     The adjustment of gradient factor is needed
8     The critical airplane that is not capable of
      operating at high altitude without modification
      is not expected
9     The selected module is runway length and
      capacity
10    The objective of this action is airfield design
11    The airfield that you are dealing with is a
      back country landing strip
12    Variable [AE] = 3000.000000
13    Variable [SPEED] = 90.000000
14    Variable [WINGSPAN] = 35.000000
15    Variable [TEM] = 75.000000
16    Variable [TAILWIND SPEED] = 3.000000
17    Variable [EFFECTIVE RUNWAY GRA] = 2.000000
18    Variable [WEIGHT] = 10000.000000
__________________________________________________
Enter number of line to change, <O> for original
data, <R> to run the data, <H> for help or any other
key to redisplay data:
```

If the user enters 12 and 15 and answers the questions, respectively, by entering 1,500 for Variable [AE], the airfield elevation, and 80 for Variable [TEM], the temperature, he or she then selects "R" to rerun. The new results will appear as follows:

```
      Values based on 0/1 system              VALUE PREV.

1     Runway length and capacity                1    1
2     The minimum requirement for approach
      area is 21 acres                          1    1
3     the airfield elevation above mean sea
      level (ft) = 1500
4     the length of runway in ft = 3475
5     the approach speed of aircraft in knots = 90
6     the length of wingspan in ft = 35
7     the mean daily maximum temperature in
      Fahrenheit for the hottest month = 80
8     the tailwind speed in knots = 3
9     the effective runway gradient in % = 2
10    the runway length adjusted by both tailwind
      factor and effective gradient factor = 4985
11    the minimum requirement for landing area
      (acres) = 35.775
12    the minimum requirement for the total
      area of airfield (acres) = 56.775
13    the maximum certificated takeoff weight
      (lb) = 10000
__________________________________________________
All choices <A>, only if value >1 <G>, Print <P>,
Change and rerun <C>, rules used <line number>,
Quit/save <Q>, Help <H>, Done <D>:
```

Comparing the results of two tables shows that:

	Alternative 1 (altitude=3000 ft, temperature=75 °F)	Alternative 2 (altitude=1500 ft, temperature=80 °F)
Runway length (ft) before adjusted by tailwind and slope	3,475	4,166
Runway length (ft) after adjusted by tailwind and slope	5,953	4,985
Minimum requirement for the total area (acres)	63	56

if "D" is selected, the system will ask:

```
Run again (Y/N) (Default=N)
```

The user may select Y to rerun or N to terminate the system.

SYSTEM EVALUATION

The system has been evaluated by three Steering Committee members and tested by an airfield expert. The results of the evaluation are summarized as follows:

(1) The system is easy to learn and use. It would take several days or weeks for an engineer to gain enough knowledge from reviewing the FAA Advisory Circulars; by using the Airfield Expert System, it only takes few minutes to select design standards for an alternative.

(2) After the system is verified, it can avoid human errors in selecting the design standards.

(3) There are drawbacks of using EXSYS, the expert systems shell. For instance, the user would prefer to see the results being displayed in the middle of the screen instead of at the upper-left corner. It is impossible for the user to make such changes.

(4) It is useful for the user to have the option of testing the effect on conclusions of changes in the input. It allows the user to evaluate sensitivity of runway length and depth.

In general, the system technology has proven to be cost-effective.

CONCLUSION

Great potential exists for the use of expert systems in engineering practice and problems. The prototype expert system presented in this article has demonstrated such potential. The hope is that the system will serve as a model for applying the technology to other engineering problems. Expert systems can be an additional tool to assist engineers in handling complicated tasks and to aid in decisionmaking.

ACKNOWLEDGMENT

The Airfield Expert System was developed under the supervision of Steering Committee members Ted Zealley, Ken Alderman, and Dayton Nelson. The system was tested by Roy Keck. Other individuals who made contributions to this system include Jerry Bowser, Douglas Bird, David Neeley, and James Trenholm.

The Airfield Expert System runs on IBM PC and compatibles, including the AT&T 6300 PC, and is available from WO Engineering. Please contact Fong Ou on the Data General at F.OU:W01B or FTS 235-3119.

Winter Travel—A Safety Reminder

It doesn't matter whether this winter is mild or whether it's hard; we may be assured that somewhere in the United States there will be snow, ice, and hazardous driving conditions. What does matter is our safety.

Many of us travel in our work, and it is time to remember that winter poses hazards for which we may not be prepared. The concern for safety shouldn't only apply to our work, but also when driving with our families and when traveling to and from work.

Try to keep these tips in mind so that you can have an accident-free winter.

MAKE THAT PLANE CONNECTION

When road conditions are poor, allow extra travel time on your way to the airport.

If your flight schedule has been changed because of the weather conditions, take precautions as you go through airport terminals. Don't get in too big of a hurry when lifting your luggage; remember to do it safely.

RENTAL CARS in STRANGE PLACES

Before driving out of the lot with your rental car, make sure the wiper blades, lights, and brakes are all in working condition. Also, make sure you have windshield wiper fluid and watch out for exhaust fumes in the car. Exchange a rental car for another car if it is in unsatisfactory condition. Plan your travel so you don't have to hurry. It is especially important to drive defensively in a car you are unsure of.

BE PREPARED

Take the proper clothing for your destination. Bring hats, gloves, and boots--especially if you will be in snow country. Also, wear sunglasses to protect your eyes from glare and sunburn, and to prevent UV damage.

WALKING

Watch your footing on slippery surfaces. Be especially careful of ice on walkways and of wet leather heels on smooth floors.

Don't venture into unknown, dark country alone.

SPORTS & STRENUOUS ACTIVITIES

Be in good physical shape before performing strenuous activities. Dress properly and stay on the safe side of fatigue.

Safety can become a natural and valuable part of our attitudes. All it takes is attention to detail and a desire to work safely.

Let's all do our best to have a safe winter.

This safety message was submitted to EFN by the Nationwide Forestry Applications Program.

Bibliography of Engineering & Equipment Development Publications

This bibliography contains information on publications produced by the Washington Office Engineering Publications Section and the Equipment Development Centers.

The listing is arranged by publications series and includes title, author/source, document number, and date.

This issue lists material published since our last bibliography (Engineering Field Notes, Volume 18, November-December 1986). Copies of Engineering Field Notes and Engineering Management Series publications listed herein are available to Forest Service personnel through the Engineering Staff Technical Information Center (TIC). Copies of the Project Reports, Equip Tips, and Special & Other Reports are available from the Equipment Development Center listed as the source.

Forest Service-USDA
Engineering Staff, TIC
P.O. Box 96090
Washington, DC 20090-6090

Forest Service-USDA
San Dimas Equipment
Development Center
444 E. Bonita Ave.
San Dimas, CA 91773

Forest Service-USDA
Missoula Equipment
Development Center
Fort Missoula, Bldg. 1
Missoula, MT 59801

Engineering Field Notes

This publication is a bimonthly periodical that supplies the latest technical and administrative engineering information and ideas related to forestry and provides a forum for the exchange of such information among Forest Service personnel.

EFN BY TITLE

EFN by AUTHOR

Cherry, Darrel B. EFN 19 (March-April 1987): 33-44.	Rehabilitation of Hume Lake Dam--First Concrete Multi-arch Dam in the United States
Chesley, John T. EFN 19 (July-August 1987): 13-19.	Getting Ahead Using the Multi-Year Schedule Program
Coghlan, Skip. EFN 19 (January-February 1987): 49-56.	Aggregate Surfacing Acceptability
Editor. EFN 19 (May-June 1987): 1-2.	Awards for the 1986 Field Notes Articles
Editor. EFN 19 (September-October 1987): 3.	Dwyer Receives Award
Editor. EFN 19 (September-October 1987): 55.	Errata (HP-41C Estimate of Uncertainty for Conventional Ground Method Closed Survey Traverses)
Editor. EFN 19 (November-December 1987): 3-4.	Road Program Costs: Continuing Efforts Addressing the Issue
Editor. EFN 19 (September-October 1987): 1-2.	ROADS Working Group Gets Thanks for a Job Well Done
Editor. EFN 19 (May-June 1987): 3-4.	Robert S. Black--Forest Service Engineer of the Year
Greer, Jerry D. EFN 19 (May-June 1987): 59-62.	A Primer on Satellite Sensors
Greer, Jerry D. EFN 19 (July-August 1987): 21-35.	An Analysis of Space Shuttle Large Format Camera Coverage of National Forests in the United States
Grosvenor, John. EFN 19 (November-December 1987): 33-37.	Multiple Resource Historic Evaluation--Lookout Tower Study, Pacific Southwest Region
Hamilton, Wayne. EFN 19 (March-April 1987): 5-8.	Buffalo Pass Turnkey
Harbin, H. Mike. EFN 19 (July-August 1987): 1-12.	Black Butte Cadastral Survey Using Global Positioning (GPS) and Photogrammetric Technologies for Control

Hochrein, Peter H. EFN 19 (May-June 1987): 35-46.	Skyline Thinning Cost Comparison for Three Yarding Systems
Hrubes, Robert J. EFN 19 (March-April 1987): 17-23.	PAIRWISE, A New Decision-making Tool Available to Forest Service Engineers
Jackson, Ron. EFN 19 (September-October 1987): 13-20.	Log Truck Performance on Curves and Favorable Grades
Johnson, Allan A. EFN 19 (January-February 1987): 41-47.	Using Fabric To Pave Over Wood Bridge Decks
Kayser, Al. EFN 19 (May-June 1987): 47-57.	HP-41C Estimate of Uncertainty for Conventional Ground Method Closed Survey Traverses
Kocmick, Lee. EFN 19 (November-December 1987): 29-31.	Continuous Belting Trail Drainage Structures
Lancaster, Jerry. EFN 19 (March-April 1987): 5-8.	Buffalo Pass Turnkey
McCauley, Dave. EFN 19 (May-June 1987): 13-19.	Mount Whitney Solar Toilet
McDonald, James G. EFN 19 (May-June 1987): 13-19.	Mount Whitney Solar Toilet
Mielke, Jack. EFN 19 (November-December 1987): 15-21.	Epoxy Injection Repair of Crane Lake Dam
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