Forest Road Reconstruction or Relocation? Cameron North Road Improvement Project

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ABSTRACT - Forest engineers need to follow a process to provide forestland owners and managers with transportation systems that meet owner objectives and legal standards. A process used to relocate and reconstruct an existing 1.3-mile road on the north portion of the Elizabeth Starker Cameron Demonstration Forest (a 260 acre timber tract donated to Oregon State University for private and family forestry) is described. Forest engineers found that careful communication with the tract manager and the forest planning board was essential. Road management objectives had to be clearly understood and documented. Forest engineers generated viable alternatives and explained associated costs, constraints, and risks. It was the forest engineer's responsibility to assure that the tract manager understood and agreed with (or made) key decisions including final route selection and design standards to avoid costly rework later. The process from initial discussions with the tract manager through final construction is described. Survey, design and analysis tools used in the project are briefly described. A restricted-use, low-maintenance, out-sloped design resulted.

Keywords: out-slope, fords, culverts, dips, drainage

INTRODUCTION

Forest engineers need to follow a process to provide forestland owners and managers with transportation systems that meet owner objectives and legal standards. A process used to relocate and reconstruct an existing 1.3-mile road on the north portion of the Elizabeth Starker Cameron Demonstration Forest (a 260 acre timber tract donated to Oregon State University for private and family forestry) is described. Forest engineers found that careful communication with the track manager and the forest planning board was essential. Road management objectives had to be clearly understood and documented. Forest engineers generated viable alternatives and explained associated costs, constraints, and risks. It was the forest engineer's responsibility to assure that the tract manager understood and agreed with (or made) key decisions including final route selection and design standards to avoid costly rework later. The process from initial discussions with the tract manager through final construction is described. Survey, design and analysis tools used in the project are briefly described. A restricted-use, low-maintenance, out-sloped design resulted. Process steps occurred in three broad phases: 1) transportation planning 2) road survey and design 3) construction.

The 260 acre Elizabeth Starker Cameron Demonstration Forest (the "Cameron Tract") was donated to Oregon State University's College of Forestry in 1995 to serve as the foundation of a new Starker Program in Private and Family Forestry. The Tract, located in the Soap Creek Valley, a rural-residential area on the fringe of Corvallis, Oregon, is actively managed to demonstrate forestry alternatives relevant to small, non-industrial private forest owners, and to produce revenue to support the Program.

Among the initial tasks in developing the Cameron Tract management plan was to establish an Advisory Board consisting of non-industrial private forest owners, Cameron Tract neighbors, consulting foresters, and OSU faculty and staff. The board was particularly concerned about developing a constructive relationship with Cameron Tract neighbors. With the gift of the property came the requirement that, in the first year of OSU ownership, a sizeable donation for the OSU library was to be generated from the sale of Cameron Tract timber. That timber sale consisted of two clearcuts along the main road through Soap Creek Valley. The harvests generated not only the necessary revenue, but also a good deal of ill will within the neighborhood.

In order to foster a more constructive relationship between the College and Cameron Tract neighbors, and to enhance communication between Soap Creek neighbors and non-industrial forest owners, we conducted an open planning process through which the views of major stakeholder groups could be heard and incorporated. Over the course of three years an Advisory Board was convened, a long range plan developed, a comprehensive Tract inventory conducted, a transportation plan agreed upon, and a stand-by-stand management plan initiated. Initial stakeholder response to these accomplishments suggests that the open, slow-moving planning process has indeed contributed to a positive, constructive working relationship in the neighborhood.

As a demonstration forest, the Cameron Tract's transportation needs are somewhat unique. Roads must not only serve management needs (access for resource management, fire control, and so on), but must also serve the Tract's educational mission. Roads must accommodate College of Forestry classes, landowner field days, and tours of visiting land managers and forest owners year-round. Moreover, the transportation system itself must offer opportunities for demonstrating road design and construction alternatives.

TRANSPORTATION PLANNING

Understand the Forest Management Plan

The forest management plan is the foundation for the transportation plan. The effective forest engineer will have a good understanding of the broader forest plan. The Cameron Demonstration Forest Management Plan was not well developed and documented when engineers were asked to develop a logging transportation plan. The tract had not been entered for approximately fifty years except for two clearcuts on the extreme north and south ends of the property that had been logged in 1996 shortly after the property was donated to the College of Forestry. Forest management planning and transportation planning resumed simultaneously beginning in 1999 when the Starker Chair position for Private and Family Forestry was filled by Dr. John Bliss.

Inventory the Existing Transportation System and Its Condition

A resource grade Global Positioning System (GPS) was used to map existing truck roads and main skid trails. Except for the more recently used roads on the extreme north and south ends of the tract, the existing road system had not been used for log haul for approximately fifty years and was over grown and partially sloughed in with approximately 10 feet of road width remaining. The road had evidently been side-cast constructed without a ditch and without rock for a dry weather logging operation in the late 1940s. The road was on ground slopes that ranged from 10 to 45 percent averaging approximately 25 percent.

Road hazards to the watershed were observed. There was evidence that some widely spaced water bars had been constructed. Some segments with grades in excess of 20 percent were deeply eroded due to drainage problems that were still persisting at the time of the inventory. No major fill failures or landslides from the existing road system had occurred. Segments of the road system paralleled small type N streams and were within the riparian management areas (RMA) (Oregon Forest Practices Act, 1971). The Oregon Department of Forestry has developed a protocol that other ownerships may use for inventorying road hazards (Forest Roads Manual, 2000).

On the north half of the tract, which is the focus of this paper, there were several minimum radius curves of 15 meters (50-feet), one of which was on a 24 percent favorable grade. Another 20 percent grade had been located perpendicular to the contours and had deeply eroded due to drainage problems. There was only one culvert in the entire road system on the north half of the tract; this culvert had long since plugged and rusted. The road had never been rocked except for spot rock placed on steep grades.

The GPS data of the road was exported to ArcInfo and a 1:4800 scale 20-foot contour map showing the existing road, streams, property boundary, and recent clear cut with major skid trails was plotted for logging systems/transportation planning. Contours were derived from light detection and ranging (LIDAR) data.

Identify Road Management Objectives

Identification of road management objectives (RMOs) is a critical early step to any road job. The burden is on the forest engineer to discover these objectives. If RMOs are not clearly identified in a forest or tract management plan, the forest engineer is well advised to collaborate with the land manager in their development before investing great amounts of time on the project.

What should be included in the RMO's? Purpose of the road, integration with logging systems, access restrictions, critical vehicle, traffic level, season of use, limitations of construction costs, duration of use, other resource concerns such as water, wildlife, visuals, dwellings downslope from the project area, or other improvements that need protecting.

Specific RMOs for the Cameron Demonstration Forest were developed during meetings with the Cameron Tract Planning Board to capture the Board's intent and direction. The RMOs were documented and agreed to in writing by the forest engineer and forest manager. They included:

1. Provide a limited-access single-lane low-impact forest road system for long-term, intermittent, dry-season log haul integrated with a ground-based logging system. Construction is to be complete by June 30, 2001 to accommodate log haul for a summer, 2001 timber sale of 300-500 MBF.

2. Provide all-season access for two-wheel drive vans, buses, and administrative vehicles to a turnaround at approximate milepost 1.0 on the existing road.

3. Provide a parking area for approximately 20 vehicles including two-wheel drive vans, school buses and administrative traffic in the existing clear cut on the north end of the tract.

4. Demonstrate low impact road designs such as out-sloped without ditch, crowned with ditch, capped and uncapped base course, un-rocked, and various drainage structures such as culverts, drivable dips and water bars, rubber belt cross drains, runoff filters, etc. Keep the road as narrow as practical.

5. Vacate sections of an old road within the riparian area of the small N stream that separates the north and south portions of the Cameron tract (Figure 1).

6. Route haul north on Soap Creek Road to State Route 99 via the Coffin Butte Road rather than over the Sulphur Springs saddle to limit noise and traffic for nearby residents.

7. Locate, design and construct the road for low maintenance (relocate difficult to drain segments that run perpendicular to contours, avoid unstable ground, layer compact fills, use bench construction on steeper side slopes, reduce the number of cross-drain culverts to maintain by out-sloping sections of the road where feasible combined with rubber belt cross drains, consider rocked fords on intermittent streams where winter traffic will be light).

8. Minimize impacts to RMAs and to water quality; do not adversely impact waters of the state.

9. Locate, design, and construct the road in accordance with the Oregon Forest Practice Rules.

10. Limit access with a lockable heavy-duty steel gate. Road running surface should not be a barrier to equestrian use (uncapped 6-inch base course would likely be a barrier to equestrian use).

Analyze logging systems and transportation opportunities
The manager of the College of Forestry student logging program and two students were asked to prepare a logging systems and transportation analysis of the forest. After intensive reconnaissance they determined that nearly the entire area could be tractor skidded downhill to the existing road system as had been done 50 years earlier. The road would not need to be rocked if logging was confined to the late summer dry season and if the road was inactivated after logging by waterbarring, revegetating, and blocking the road to motorized travel. The analysis also indicated that log haul could go uphill to an existing road system on adjacent land instead of down hill to the existing county highway. Approximately five percent of the area would require a gravity skyline system. Preparation of a logging and transportation plan would have been very straightforward, were it not for the RMOs!

The forest manager and planning board wanted the first mile of the road open to vans and school buses year round for tours and demonstration purposes. The transportation planners realized that a rocked running surface would be required if the road was to be open to motorized travel from mid-September through mid-June due to seasonal wet conditions in the Willamette Valley. Additionally, two steep sections of the existing road with drainage problems would need to be relocated if the road was to remain open year round. Another challenge was that approximately 335 meters (1100 feet) of the existing road paralleled a small stream and was within the riparian area. Portions of the old road were within three meters (ten feet) slope distance of the high water level of the stream. Road stewardship practices called for vacating the section of the old road that paralleled the riparian area (Cornell and Mills, 2000). The emerging forest plan was calling for a small sale of approximately 300-to 500 thousand board feet to be prepared on the north section of the forest during the 2001 operating season followed by frequent re-entries to place treated stands on an uneven-aged trajectory. This would affect dollars available to upgrade and maintain the road. It became evident that the entire road system could not be upgraded at the same time due to the capital investment required; therefore the decision was made to only upgrade the road system on the north portion of the forest in 2001.

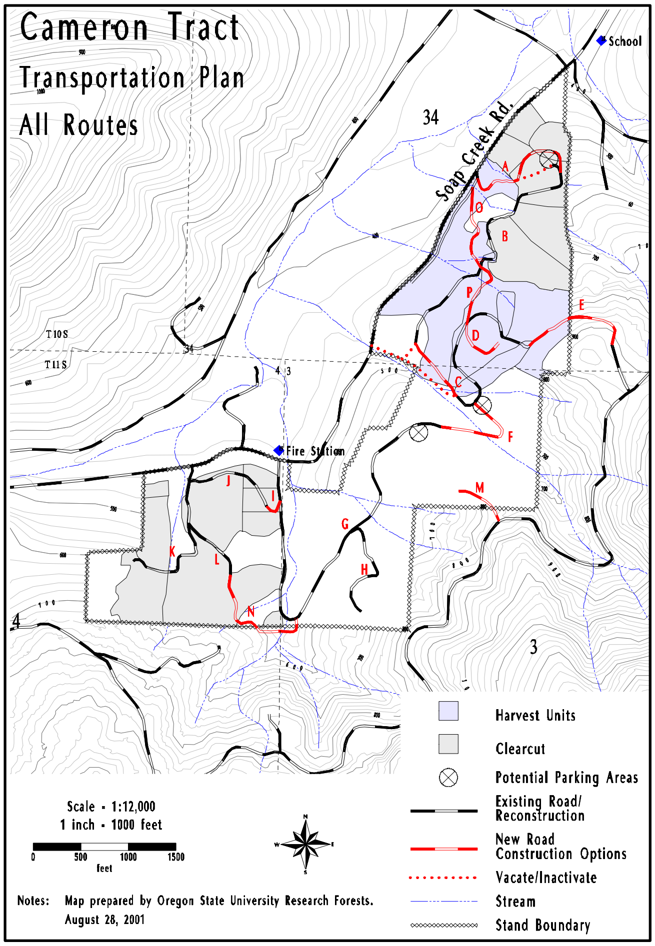

Figure 1. Road segments A, B, C, D, E, O, and P provided various combinations of reconstruction and relocation alternatives to access the harvest unit in the north portion of the tract.

Alternative routes were flagged in the field. Alternative routes were added to the 20 foot contour LIDAR contour map. There were too many alternative routes to subjectively analyze (Figure 1). Fixed and variable costs of various road segments were estimated. The data was input to Network 2000 (Sessions and Chung) and six different haul alternatives were analyzed. The results were shared with the forest manager.

The north and south portions of the forest were divided by a deeply incised stream. The forest engineer arranged to walk the alternative routes with the tract manager, the Oregon Department of Forestry forest practice forester and geologist. The geologist assessed a proposed location that could connect the north and south portions of the forest for landslide and debris flow danger to a downstream dwelling in light of Senate Bill 12 which was a July, 1999 revision to the Oregon Forest Practice Act that provided for public safety below steep, unstable slopes on forestland. The assessment indicated that channel morphology would not legally prohibit crossing the stream with a carefully designed structure. The geologist suggested relocating another section to solve a drainage problem.

Decide on Location

After the review, the forest manager discussed the alternatives with the forest engineer and chose alternative C (Figure 2.). The route chosen by the manager was 2.0 kilometers (6700 feet) in length. The first 1,600 kilometers (5,250 feet) were to be rocked for all season tour traffic. The last 434 kilometers (1,420 feet) were to be native surface. Seventy-five percent of the selected route was reconstruction and twenty-five percent was relocated new construction. The selected route would cross small non-fish streams at 7 locations. Ground slopes varied up to 45 percent.

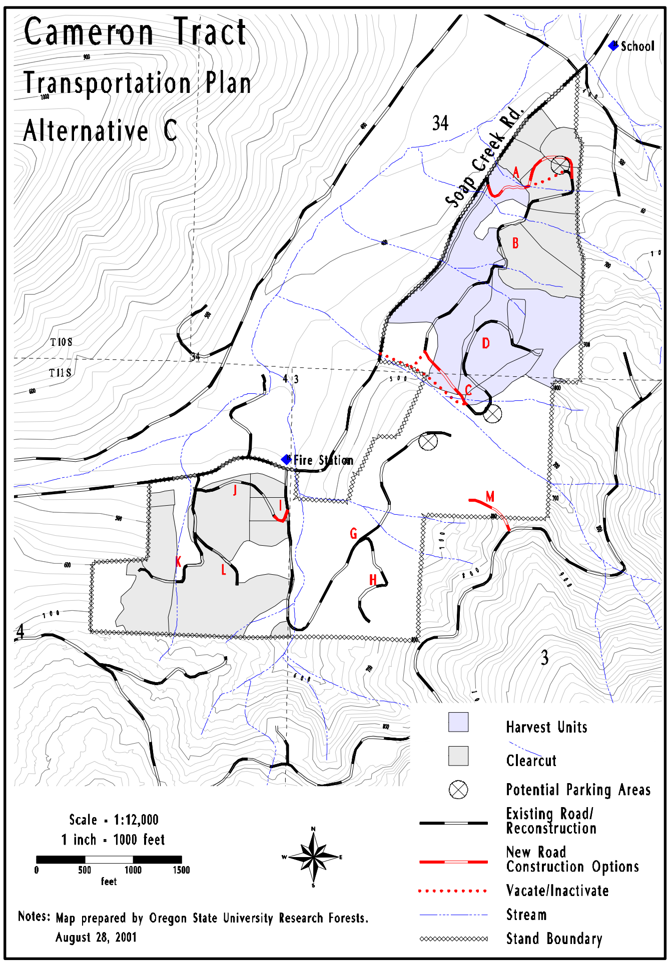

Figure 2. Alternative C (Cameron North Road) was selected to access the harvest unit in the north portion of the tract.

Alternative C was estimated to cost $13,744 more than the lowest cost alternative; however, the manager made the decision with knowledge of the tradeoff cost from Network 2000. The decision rationale was documented in the transportation plan as follows:

Alternative C is the selected alternative for the following reasons:

1. Uses existing take off from Soap Creek Road which provides site distance and haul direction toward State Route 99 via the Coffin Butte Road and achieves RMO number 6;

2. uses the existing road system locations which can be drained, are less than 20 percent grade, and which do not infringe on the riparian area of a small type N stream which bisects the Cameron Track north and south sections to achieve RMO numbers 5 and 8;

3. relocates sections to eliminate two 20 percent favorable grades with problematic drainage to help achieve RMO number 7;

4. vacates an existing section parallel and adjacent to a small N stream to achieve RMO number 8, and eliminates the need for a road use agreement with a private landowner;

5. provides access to a large parking area to achieve RMO number 3;

6. provides access for downhill ground-based logging systems to achieve RMO number 1;

7. provides access to a turnaround near the middle of the Cameron Tract that achieves RMO number 2.

8. does not impact the northwest portion of stand 3407 with new road construction to help achieve RMO number 4 (Road segment "O" will not be constructed).

9. total fixed and variable cost of Alternative C is mid-range compared to A, B, D, and E (Appendix A).

10. total fixed and variable cost of Alternative C is $13,744 more expensive than the unconstrained solution; however, the unconstrained solution does not meet the objectives of haul direction via Coffin Butte, minimizing impact to stand 3407, and providing all weather parking accommodations for 20 vehicles including vans and school buses in the existing plantation. (The unconstrained solution builds segments O, P, ½ of D, and ½ of B. Forest engineers can use network analysis to help forest managers make informed decisions concerning the incremental cost of adding constraints to least-cost solutions.)

11. defers the decision to connect the north and south portions of the forest by crossing a deeply incised stream without eliminating the option in the future.

ROAD SURVEY AND DESIGN

Survey

The preliminary line (P-line) survey was done by Oregon State University College of Forestry students and the forest engineer December, 2000. The survey was done with a Laser Technology Criterion 400 survey laser mounted on a monopod. The traverse, elevations, and cross-sections were all measured in one pass by a three to four-person crew. The laser was fast and had the ability to measure distance and vertical and horizontal angles. Although the laser precisely measures distance, the crew noticed a one to two percent difference in foresight and back sight vertical angles on short shots between P-line stakes. This was due to parallax since the aiming scope on the laser is mounted above both the sending and receiving apertures on the instrument. This problem can be mitigated by adjusting the scope for short distance shots.

The crew used a tape and clinometer for cross-sectioning when shots were less than about 3 meters (10 feet).

Measures were taken to guard against vandalism of P-line stakes. 50mm x 50mm x 305mm (2in. x 2in. x 12in.) wooden hubs were driven in flush with the ground to make them almost impossible to pull out by hand. Tops of hubs were painted florescent orange. Hubs were intermittently referenced to trees outside of the clearing limits with aluminum nails and tag. P-line stationing was painted on 1.2 meter (4 feet) lath. Lath was offset right or left from the hubs on reconstructed sections to protect from trampling.

P-line station 0+00 and three other P-line stations were tied to the Oregon State Plane Coordinate System using a Trimble global positioning system 12-channel Pro XR receiver with beacon.

Decide on Design Standards

The location and design standards were documented in a short report and the engineer asked the manager to sign the approval line. By so doing, the engineer and manager had a clear understanding and written documentation on where the new road was to be constructed and to what standard. This step in the process is important to eliminate costly rework or dissatisfaction with the final product. The ball was now back in the engineer's court. Design standards for the Cameron North Road included the following:

1. Design vehicle: summer - log and rock trucks to P station 67+14; winter – 2-wheel drive vans and school buses to P station 51+48 (RMOs 1, 2, 3, 6, and 9)

2. Design speed of 10 mph (RMO 4)

3. Minimum impact to soil, watershed, and visual resource (RMOs 1, 4, 5, 7, 8, 9, and 10)

Note: Different road construction designs will be demonstrated on Segments A, B, C, and D as follows: Segment A (Intersection with Soap Creek Road to end of Parking Area at P station 14+01) - This segment will be designed to handle summer log truck traffic and all-weather administrative and visitor traffic. It will be rocked and will demonstrate minimum radius curves, a through cut, unbalanced cut and fill sections, balanced sections, out-slope road sections for approximately 600 feet, and a drivable dip or intermittent ford at approximate P station 5+47; Segment B – this reconstructed segment will be out-sloped for its entire length and it will be rocked. A rocked high-water ford will be constructed across two swales (intermittent streams) and a culvert will be installed in another intermittent stream; Segment C will be a rocked new construction section to a turn-around. Section C will be out-sloped between approximate stations 42+69 to 49+17. A 24 to 30 inch culvert and fill will be installed at station 49+17. A ditched section will be constructed from approximate P-station 49+17 to 49+98 where water from an old road will be intercepted to stop erosion; Segment D will be reconstructed without rock and out-sloped its entire length. A landing at the end of Segment D may be rocked.

Design Elements

1. 12 foot running surface plus curve widening and widening for turnouts, intersections, landings and for a 20-vehicle parking area (RMOs 1, 3, and 4)

2. Out-sloped subgrade without ditch on grades less than 10 percent where significant quantities of ground water are not expected from cut-slope interception and built to minimum width to achieve running surface width

3. Crowned subgrade with one-foot deep ditch on grades greater than 10 percent and where significant quantities of ground water are expected from cut-slope interception. Build to the minimum width to achieve the running surface width. Ditch slope to sub-grade will be 2:1.

4. ¾:1 cut slopes

5. 1-1/2:1 fill slopes

6. Cross drainage on out-sloped sections provided by 3 to 4 percent out-slope, drivable dips, drivable water bars, rubber belt cross drains

7. Cross drainage on crowned section with ditch provided by 18-inch high density polyethylene pipe or corrugated metal pipe.

8. 3-inch minus base course to turnaround (P station 51+48) at sufficient thickness to support traffic.

9. Cap base course with 1-1/2 inch minus aggregate to parking area (P station 12+78 to 14+01) and on any rocked grades exceeding 12 percent.

10. Move the lockable gate far enough off Soap Creek Road to accommodate an unloaded log truck with piggybacked reach.

11. Minimum turn radius of 60 feet.

12. Entry point onto Soap Creek Road is to meet county standards and provide access to route 99 via the Coffin Butte Road (accomplishes RMO 6).

13. Designate stable waste areas.

14. Drain, block, and sign sections of existing roads to be vacated.

15. Slash disposal of clearing and grubbing debris by scattering.

16. Clearing limits in new construction sections: 3 feet above top of cut to toe of fill; Clearing limits in reconstruction sections: 3 feet above top of cut to toe of fill.

17. Provide for takeoff at 1+40 to landing just across small stream.

18. Post appropriate road closed signage just beyond the turn-around to close the remaining portion of the road from October 15 to June 15 and during wet periods.

Design

The offset paper design method was chosen for the entire length of the Cameron North Road. RoadEng^{TM} by Softree Technical Systems, Inc. was used to design the road and to output quantities, drawings, and staking notes. A minor problem was encountered with road surfacing display and quantities on out-sloped cut and fill sections in that surface aggregate could not be placed against the cut slope. Rock quantity was easily adjusted by hand computation. There was no problem with rock quantity in thru fills or cuts.

The USFS *Earth and Aggregate Surfacing Design Guide for Low Volume Roads* (Bolander et al, 1996) was used to determine aggregate thickness. The guide indicated that 20 centimeters (8 inches) of compacted aggregate would give a reliability level that ruts would be less than five centimeters (two inches) deep over 90 percent of the project length after expected log haul and administrative traffic. Two 10-centimeter (4-inch) compacted layers of well-graded 3.8 centimeter (1-1/2 inch) minus crushed aggregate were selected for the surface design. Pit-run base course and fabric was added to strengthen the pavement in less well-drained sections of the road. Interestingly, fabric and pit-run base course was used on 9 percent of the project length after modifications to the original design. The out-sloped Cameron North Road is to be re-graded and rolled after log haul and before the rainy season to remove ruts and to reseal the road for all season classroom and tour traffic on the rocked section.

Four in-stream culverts were designed to withstand the 50-year flood as required by the Oregon Forest Practice Act. A 0.5 headwater to depth ratio was used to size the inlet controlled culverts on the Cameron North Road instead of the more commonly used ratio of 1.0 to allow for partial plugging that is likely to occur during major storm events and to reduce discharge velocity at the outlet. The streams were non-fish bearing so fish passage was not a design criterion. The design strategy as described in the *Oregon road/stream crossing restoration guide* is an excellent reference for the engineer needing to design a fish passage structure (Robison, E., et al, 1999).

The forest engineer should consider cost effectiveness when choosing a survey and design method. The level of accuracy needed, side slopes, grades, tight curves, drainage structures, traffic level, resources, condition of existing road, and other road management objectives need to be considered. In retrospect, field design may have been adequate and more cost effective for the un-rocked portion of the Cameron North Road. Successful results with field design require a high level of skill on the part of the engineer as well as some help from the road construction contractor. Paper design and staking is time consuming, but was the right choice for most of the Cameron North Road in the engineer's opinion.

Plan-in-hand field review
A plan-in hand field review of the draft road design is an important step. Improvements to the design are invariably discovered during a plan-in-hand review.

Prepare Contract
A contract for the Cameron North Road was prepared for advertisement through Oregon State University Facilities Services. The contract included 28x43 centimeter (11x17 inch) RoadEng™ multi-plot sheets of plan, profile, and mass haul.

Cost Estimate
The engineer's estimate for the project was $62, 925.

Prepare Notification and Written Plan
The Oregon Department of Forestry was notified of the proposed road construction in accordance with the Oregon Forest Practice Act. A written plan was not required since no part of the project was within 100 feet of a fish stream.

Construct
The forest engineer staked the road with the assistance of students and staff. A hand level, level rod, range pole, and steel tape were used. It took approximately 80 person hours to stake catch points for 146 sections on the 2,040 meter (6,690 feet) long road. None of the students had prior staking experience, so considerable time was spent in training. Cut stakes were referenced with hubs and lath. Line stakes were set upslope from reference stakes. Culverts, fords and

turnout extents were also staked. Time could have been saved by only staking one side of the road; however, control of road width during construction administration was easier with catch points staked on both sides of the road. Clearing limits on the cut side were flagged concurrently with staking.

Overburden in the form of sod was scraped off with a D4 crawler tractor. Approximately 205 cubic meters (41 thousand board feet) of rights-of-way timber was felled, limbed, and bucked manually. Many trees in the 51 to 91 centimeter (20 to 36 inch) diameter size range had encroached into the clearing limits on sections of the existing road that were to be reconstructed. Logs were decked by a rubber-tired skidder or by the excavator. Stumps were grubbed by the excavator. Stumps and slash were disposed of by scattering. Ten of the larger root wads were end-hauled to waste areas to maintain the visual resource.

Excavation was done with a combination of machines including D-4 and D-6 crawlers, a small and large excavator, and a backhoe. A 12 yard dump truck was used for overhaul. Most of the excavation was done with the D-4 crawler due to the narrow width of the road. Fills were brought up to grade in 20-centemeter (8-inch) layers. Each layer was compacted with a vibratory sheep's foot roller (Figure 3). Out-slope of the sub-grade was checked with a 12 foot board with level set at the proper angle (Figure 4). A 4 to 5 percent out-slope was required on the first half of the road. A 3 to 5 percent out-slope was required on the second half of the road.

Figure 3. Dozer and sheepsfoot roller work together to bring fill up to grade in compacted layers for sub-grade stability on a segment of relocation.

Bench construction was required on a 200 foot section of new construction that was on a 40 percent side slope. Although the section was not fully benched, the bench construction strengthened the fill. Fill failures on a narrow out-sloped road must be carefully guarded against.

Culvert ends were staked and troughs were excavated. Select material or ¾ inch minus aggregate was used for bedding. Backfill was hand compacted in layers with a jumping jack compactor. Culvert fills were armored with class 100 rip-rap. The sag point of a vertical curve over a 36 inch culvert was offset 9 meters (30 feet) from the culvert (Figure 5). This reduced the amount of fill likely to wash in the event the culvert plugs and water overtops the road. Fish passage was not an issue since the streams were not fish bearing.

Fords were constructed with a 43-centimeter (17-inch) layer of open graded pit-run rock over fabric. Class 100 rip rap was placed immediately upstream and downstream of the fords. The streams were dry when the fords were constructed (Figure 6).

Figure 4. Subgrade of a reconstructed segment being checked for 4 percent outslope with a 3.7-meter (12-foot) board and angled level prior to rocking.

Figure 5. Sag point of the vertical curve offset from the culvert to protect the fill on a relocated section

The Contractor purchased crushed 3.8 centimeter (1-1/2 inch) minus aggregate rock from a private source. The rock was tested and met the hardness, durability, and gradation specification in the contract. Dumping distances for the first 4-inch lift of aggregate were marked on the truck driver side of the road. Aggregate was processed by alternately watering and turning three or four times with a grader for mixing prior to spreading in 4-inch layers. Layers were compacted in two 4-inch lifts with a smooth-drum vibratory roller. Compacted rock depth was checked at centerline with a hand level held against a level rod while sighting on reference marks placed on 4-foot lath on the cut side of the road.

Figure 6. A ford constructed across an intermittent stream.

The contractor elected to start placing rock at the end of the project and progress out toward the beginning of the project. This allowed rock trucks to find soft spots during haul. Soft spots developed even though the sub-grade had been layer compacted in 20 cm. (8 inch) lifts by a sheep's-foot vibratory compactor. Soft spots were strengthened as they developed with compacted pit-run rock. Fabric was placed over pit-run rock where rutting had progressed more than 10 cm. (4 inches). Fabric was placed under pit-run base course where rutting had started but which had not occurred to a significant degree. Fabric was placed on approximately 9 percent of the rocked portion of the road.

Two rubber belt cross drains were installed by the contractor on 12 and 14 percent road grades after rocking had been completed (Figure 7). The cross drains were constructed by students in accordance with a design by Brian Kramer, P.E., Senior Instructor, Forest Engineering Department, College of Forestry, Oregon State University. Students lag screwed heavy-duty conveyor belting cut in 30 centimeter (12 inch) wide by 6 meter (20 foot) long strips onto the edge of treated 10x20 centimeter (4x8 inch) treated timbers. The contractor buried the timbers in the aggregate with approximately 10 centimeters (4 inches) of the belting protruding above the surfacing of the out-sloped road. The drains were skewed approximately 45 degrees.

DISCUSSION

Cost

An invitation to bid (ITB) on construction of The Cameron North Road Improvement Project was widely circulated to contractors by Oregon State University's Facilities Services Office as a public works contract subject to prevailing wage rates. Six bids were received ranging from $90,834 to $112,768 including slope staking. Slope staking was advertised as a deductive bid item in the ITB. Contractors' bids for staking ranged from $6,985 to $14,681 (US dollars). Bids for slope staking were rejected. The contract was awarded to the low bidder without staking for $76,584. The forest engineer staked the road for approximately $2,400 with the help of students and staff.

Road construction costs including engineering for the Cameron North Road were tracked by three road types: 1) reconstruction rocked 2) reconstruction not rocked 3) relocation rocked (new construction rocked). The greatest difference in cost per kilometer was dependent on whether or not the road was rocked (Table 1). The addition of rock to reconstructed segments increased the cost 221 percent over reconstructed un-rocked segments. In comparison, there was relatively little difference in cost between rocked reconstruction and rocked relocation. Surprisingly, relocated segments cost 11 percent less than reconstructed segments that were rocked. In the case of the Cameron North Road, there were more drainage structures per kilometer needed in reconstructed segments than were needed in the relocated segments. Also, less fabric and rock was needed per kilometer in relocated segments. Rock accounted for 59 percent of the total cost of the rocked portion of the road (Table 1). Engineering accounted for 11 percent of the total cost of the road (Table 1).

Figure 7. Installing a rubber belt cross drain on a relocated out-sloped section.

The final construction cost excluding slope staking and other engineering was $93,260 or approximately 22 percent higher than the bid price. Reasons for the overrun in construction cost were the need for an additional 876 tons of pit-run and aggregate rock at a cost of $9,537 to strengthen soft sections which became evident during rock hauling, an underestimate of 86 tons of class 100 rip rap at a cost of $2,505 needed to more fully armor culvert fills, an underestimate of 171 cubic yards of compacted fill material at a cost of $1,220 needed to construct the road (the 1.4 fill expansion factor used to estimate in-place bank excavation quantities should have been closer to 1.6 due to larger than expected quantities of unsuitable sod that had to be stripped from reconstructed sections of the old road), a design change to increase the out-slope from 3 percent to 4 to 5 percent and to daylight several through cuts on the first half of the road at a cost of $2,134, an additional 500 square yards of fabric at a cost of $500, the addition of two belt cross drains at a cost of $309 each and a concrete culvert extension at the take off from the county road at a cost of $162.

A cost increase of approximately fifty percent per installed culvert was experienced by decreasing the headwater to depth ratio from 1.0 to 0.5 for the Cameron North Road in-stream culverts. In retrospect, a more cost effective design would have been to size the culverts using a headwater to depth ratio of 1.0 but for the 100-year storm.

Watershed Enhancement

The Oregon plan for salmon and watersheds was reaffirmed January, 1999 “to restore Oregon’s wild salmon and trout populations and fisheries to sustain productive levels that will provide substantial environmental, cultural, and economic benefits and to improve water quality”

(Executive Order No. 99-01, the Oregon plan for salmon and watersheds). An essential principle of the plan is to encourage efforts to improve conditions for salmon through non-regulatory means. The Cameron North Road Improvement Project will help to improve the health of the Soap Creek watershed by vacating approximately 0.3 kilometers (0.2 miles) of road within the riparian management areas of small non-fish tributaries, by placing aggregate surfacing on 1.1 kilometers (0.7 miles) of existing non-surfaced road, and by improving six crossings of non-fish bearing tributaries to Soap Creek. These improvements will be reported to the Oregon Watershed Enhancement Board that monitors improvement projects that help to achieve the purpose of the Oregon Plan.

Table 1. Cost Itemization by Road Type

Item	**Reconstruction rocked**	**Reconstruction not rocked**	**Relocation Rocked**	**Total**
Engineering 1/	$6,474	$2,567	$3,012	$12,053
Clear/grub	$3,978	$1,578	$1,850	$7,406
Excavate	$8,524	$2,534	$4,192	$15,250
Rock	$38,492	0	$15,060	$53,552
Fabric	$778	0	$53	$831
Fords	$2,263	0	$1,225	$3,488
Culverts	$2,949	0	$1,231	$4,180
Belt drains	$309	0	$309	$618
Move gate 2/	$403	$160	$187	$750
Mobilization 2/	$3,863	$1,532	$1,796	$7,191
Total	$68,033	$8,371	$28,915	$105,319
Length km (mile)	**1.09 (0.68)**	**0.43 (0.27)**	**0.52 (0.32)**	**2.04 (1.27)**
Cost/kilometer	**$62,415**	**$19,467**	**$55,606**	
Cost/mile	**$100,047**	**$31,004**	**$90,359**	
Cost per station	**$1,895**	**$587**	**$1,711**	

1/ Engineering cost includes transportation planning, survey and design, slope staking, and on-site contract administration minus office overhead.

2/ Costs for mobilization and for moving the gate were prorated among the three road types.

SUMMARY

Forest engineers need to follow a process to provide forestland owners and managers with transportation systems that meet owner objectives and legal standards. The sequential process used during the Cameron North Road Improvement Project included the following steps:

TRANSPORTATION PLANNING
    Understand the Forest Management Plan
    Identify Road Management Objectives
    Identify Alternatives
    Decide on Location

SURVEY AND DESIGN
    Survey
    Decide on Design Standards
    Design
    Plan-in-Hand Review
    Prepare Contract
    Estimate Cost
    Prepare Notice and Written Plan

CONSTRUCT
    Construct

Critical communication milestones between the forest engineer and the forest manager included:

Identification of the Road Management Objectives

Decision on Location and Design Standards

Plan-in hand field review

Construction Costs

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