

Native Plant Restoration on the Going-to-the-Sun Road, Glacier National Park

David E. Lange
Joyce Lapp

Abstract—Since 1991, 53 acres of roadside vegetation and soil were removed along sections of the historic Going-to-the-Sun Road during road rehabilitation activities. Restoration strategies used indigenous plant material to re-establish plant cover, prevent erosion, compete with exotics, and improve aesthetics. From several hundred collections, simple seed mixes were created that included early colonizers and late seral species. Native forbs, shrubs, and trees were propagated as bareroot and containerized material. Grass was grown as seed and increased to larger quantities with off-site seed production plantings. Revegetation incorporated a combination of plant and soil salvage, seeding, inplanting, and natural regeneration. Our monitoring program was used to assess results and to help make decisions about species selection, seeding rates, successional strategies, and realistic objectives for restoration.

Glacier National Park is one of the world's most significant natural areas containing spectacular topography, active glaciers, and unique biotic diversity. It is located in the Northern Rocky Mountains of Montana at the center of an extensive ecosystem stretching from Banff and Jasper National Parks in Canada south to Yellowstone and Grand Teton National Parks. This is an internationally significant location from the standpoint of scientific, aesthetic, and conservation values.

The Going-to-the-Sun Road is the primary way visitors see Glacier National Park. It is renowned for its scenic beauty, historic value, and unparalleled driving experience. Nearly two million visitors travel the road annually. The historic qualities of the road, combined with the vegetation, rock, and scenery, are key parts of the experience for visitors to Glacier National Park. The National Park Service manages this Road to preserve its cultural and natural values as well as to maintain the unique visitor experience.

The Going-to-the-Sun Road was constructed in 1932 as the only road linking the Park's east and west sides across the Continental Divide. Construction, which carved a road out of the mountainside, was truly an engineering feat. This unique road was designated a National Historical Landmark in 1997 because of its design significance. It was the

first park road built in this country in cooperation with the Federal Highway Administration. With passage of the National Surface Transportation Assistance Act of 1982, Congress recognized a nationwide need for rehabilitating and upgrading roads in the National Parks. The National Park Service, in partnership with the Federal Highway Administration, established a road improvement program. Glacier National Park became a participant in 1984. Since then, there have been seven road projects funded for Glacier at a total cost of \$25 million.

Restoration Program

When native vegetation was removed as part of the construction process, the consequences included erosion, invasion by exotic plants, displacement of animals, loss of screening or buffers, and reduced aesthetic value. Our restoration strategies sought to emulate structure, function, diversity, and dynamics of the adjacent plant community. Indigenous plant material was used to maintain genetic integrity and diversity. Soil and plants were salvaged and stored for replanting after construction. Native seed and cuttings were collected annually and propagated in the Park's native plant nursery and greenhouse. Seed was sent to the Natural Resources Conservation Service Plant Materials Center in Bridger, MT, for storage or for increased production, or sent to private contractors for propagation. A resource crew implemented revegetation plans and monitored results.

Goal

The goal for restoration is that within 5 years following construction, a vegetation cover of native plants is established that blends with the adjacent plant communities, is ecologically compatible with the surrounding community, and is consistent with functional maintenance and safety requirements.

Objectives

The project-specific, goal-oriented, and measurable objectives are to:

- Preserve genetic integrity of native floral populations
- Provide for optimum survival and vigor of plant material by using species collected at or near the disturbed site
- Quickly provide plant cover to stabilize soil and prevent erosion

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David E. Lange is Natural Resource Specialist, Glacier National Park, West Glacier, MT 59936. Joyce Lapp is Natural Resource Specialist (Restoration), Glacier National Park, West Glacier, MT 59936.

- Keep coverage of exotic plants low in cut-and-fill slopes and prevent invasion into undisturbed site
- Restore species composition and structure that blends in aesthetically and ecologically with adjacent, undisturbed plant communities
- Use roadside vegetation that will not be a long-term food attraction to wildlife
- Select vegetation that is low maintenance, durable, safe, and able to stand up under heavy foot and automobile traffic
- Provide opportunity for research and technology transfer

Partnerships

Since 1986, Glacier National Park has used partnerships in planning, designing and constructing seven road projects within Glacier National Park. Nearly 53 acres of roadside disturbance have been revegetated through varied habitats along the Going-to-the-Sun Road. Revegetation costs range from 4 to 8 percent of construction project costs. Budgets have included 3 percent for administration, 40 percent for plant production, 32 percent for revegetation, 14 percent for monitoring, and 11 percent for planning and design. Engineering and construction specifications were modified to reflect a high degree of consideration for the existing flora and fauna.

Planning efforts began with an interagency core team to define long-term goals and measurable objectives for revegetation. Strategies were tested on the local Coram Experimental Forest and Biosphere Reserve on road cuts similar to those on the Going-to-the-Sun Road. Interagency Agreements were completed with the U.S. Forest Service and the Natural Resource Conservation Service for technical assistance. Revegetation strategies were evaluated through a peer review process with the National Park Service Denver Service Center. Implementation of revegetation was accomplished through partnering strategies with the Federal Highway Administration and the National Park Service. A cooperative greenhouse at the local high school was constructed to grow additional plant materials while involving students and their parents in the Park revegetation program.

Lake McDonald Section, 1991

This was the first Federal Lands Highway Program in Glacier National Park. The project involved 10 miles of roadside along Lake McDonald within a cedar-hemlock forest. Through partnering and teamwork we formulated strategies that were tested at the Coram Experimental Forest. During the revegetation of 12 acres of roadside, we learned to integrate restoration activities with the planning, designing, and construction activities of a road project. We refined our methods to collect, propagate, plant, and protect indigenous species.

St. Mary to Rising Sun, 1993

This project was located within aspen parklands and fescue grasslands for 9 miles along St. Mary Lake. The Park staff learned to work with large machinery on steep slopes

to salvage and replace topsoil. They saw the advantage of taking steep slopes down to 2:1 slope if possible for long-term retention of plant material. Clearing limits were designed to avoid straight lines. The combination of salvage, regeneration, seeding, and inplanting worked together for best results. Within grassland communities we met the challenge of integrating noxious weed control and herbicides with reseeding strategies. We saw advantages to enlarging cut slopes to smooth out the transition of berms in old back-slopes. Although labor intensive, we saw positive results with hand seeding and hydromulching. Slopes were left in a roughened condition with an uneven transition to the undisturbed area.

Logan Pass, 1995

The Logan Pass project is located on the crest of the Continental Divide at an elevation of 6,600 ft. The area is snow-covered, frigid, and wind-blasted for up to 9 months of the year, with an extremely limited growing season. Visitation to this fragile subalpine environment was estimated at 1.5 million visitors each season. This project used all the experience, partnerships, and teamwork accumulated from past projects. Three acres of disturbance was treated to re-establish soil and vegetation to roadside subalpine areas. Comprehensive site analysis, planning, seed collection, and plant production were needed, and over 55,000 containerized plants were prescribed. Restoration strategies included soil and plant salvage, imported soil pasteurization, mycorrhizal production and plant inoculation, planting, seeding, mulching, irrigation, monitoring, and protection.

Site Conditions

Site analysis was a procedure that was designated to collect information on revegetation sites prior to the disturbance. Through this process, strategies were developed in the revegetation plan that were designed to overcome factors of site conditions in order to achieve the goal and objectives.

Topography

The Going-to-the-Sun Road was built through rugged mountainous terrain with elevations that ranged from 3,100 ft at Lake McDonald to 6,600 ft at Logan Pass and down to 4,500 ft at St. Mary. The road travels through the forested Lake McDonald valley for 20 miles to the base of the upper mountains. At this point, the road was carved out of the mountainside and traversed steep cliffs for 10 miles up to the Continental Divide at Logan Pass. From here the road travels down the east side into the St. Mary valley, along St. Mary Lake to prairie grasslands at the base of the eastern Rocky Mountain front.

Soils

Soils are typically gravelly fine sands and silts from sedimentary bedrocks of argillites and limestones. Volcanic ash and loess deposits had a major influence on surface soil

development, with resultant fertility and moisture-holding characteristics. The degree of weathering influenced the amount of clay in the soil profile, the thickness of the soil profile, the amount of organic matter, and water-holding capacity. For example, the soils at Logan Pass were very shallow, but in the fescue grasslands they were deep and well developed. Soils were classified along the Going-to-the-Sun Road based on a field inventory of landforms. Landforms were structural configurations of the topography that resulted from past and present geological activity. The soil component was interrelated with vegetation, drainage, and climate to determine the land-type designation.

Weather and Climate

The mountainous character of the area has marked effects on its climate, which varied widely within short distances. Average annual precipitation ranges from 28 inches at the lower elevations to 100 inches on the Continental Divide. At the lower elevations, snow was on the ground typically until May, with an average 90 day growing season. At Logan Pass, there were 60 snow-free days when planting could occur. Harsh weather and persistent snow did not allow access to this project site until late June or July. Even then, stormy weather often altered work schedules.

Diverse Plant Communities

The Going-to-the-Sun Road passes through four distinct ecoregions: montane forest, subalpine meadow and forest, aspen parkland, and fescue grassland. Species lists for restoration included over 100 species made up of several hundred collections. Seed mixes needed to not only provide revegetation species for the ecoregions, but provide for site variability within each project area. For example, the subalpine plant community had a very shallow soil with varying ranges of hydric to xeric conditions. Within the Logan Pass project area, there were seven microsites of mostly herbaceous plants. This complex arrangement of plants, with variable growing requirements, created challenges for nursery and greenhouse operations.

The plant communities along the Going-to-the-Sun Road included exotic plants and five noxious weed species. In 1991, an Exotic Vegetation Management Plan was implemented that used Integrated Pest Management to devise strategies to control exotic plants. These strategies included inventory, monitoring, education, prevention, research, and control. Herbicides were used along this Road to contain and reduce populations of noxious weeds. Monitoring results indicated optimism in reducing exotics while still retaining species diversity of native plants.

Wildlife

The wide diversity of habitat types was reflected in a similar diversity of fauna, including several endangered or threatened birds and mammals and many rare species. People stopped along roadsides to watch and follow wildlife, which resulted in trampling of natural vegetation and loss of soil. Work schedules were modified when grizzly bears passed through the project to prevent undesired encounters. Some project areas were closed for periods during the season to protect wildlife, such as nesting bald eagles.

Visitor Use

The Going-to-the-Sun Road was the primary route of travel for two million people visiting Glacier National Park, and this was concentrated during a 3 month period in the summer. The road was open during construction, with flag persons directing traffic. Overflow roadside parking, congestion, and social trails were evidence of visitor use that was greater than the developed areas could handle. The challenge was not only to restore vegetation to the areas disturbed by construction, but to protect it from very high levels of visitor use.

Past Construction

Unresolved problems of past construction continued to worsen each year, such as erosion and slumping soil on over-steepened slopes. Some of these were corrected during the new road work if they were within the project area. Examples included taking steep slopes down to a gentler grade to retain vegetation, smoothing out lips of cuts, and weaving clearing lines to blend in with natural openings.

Construction Specifications

The construction zone had tight limits for work to confine impacts to within the project area. Often construction limits were immediately adjacent to pristine meadows and watercourses. Because the road was open during construction, there was congestion with visitor traffic, which made access to the project areas difficult. Coordination between the contractor and restoration crews was critical to site preparation and planting.

Seed Collection

Large quantities of native seeds and plants were required for the revegetation of each segment of disturbance on the Going-to-the-Sun Road. Collection and propagation of this material required several years of advance planning prior to construction. In 1992, Glacier National Park established genetic guidelines for restoration projects to minimize the possibility of genetic contamination to the existing native vegetation adjacent to a disturbed site. Genetic guidelines required collections to be within the same habitat type, elevation, aspect, and drainage as the species removed during construction. Large numbers of individuals were collected among separate populations within similar community types. Over the last 12 years, the staff of Glacier National Park has made several hundred collections of over 100 different native plant species for restoration work.

Species selection was based on the predisturbance site analysis and the projections of what site conditions would be like after construction. Species lists and planting palettes emphasized colonizer species and included mid- and late-seral species to provide a better blending of the disturbance with the adjacent undisturbed vegetation. The Logan Pass project required a mix of 10 grass or carex species, 26 forb species, and five shrub and tree species. Seven distinct planting prescriptions were developed to address the extreme variables in soils, moisture, topography, and plant communities throughout the 3 acre project.

Seed collection was extremely time consuming and expensive because conditions varied from project to project and from year to year. Collection sites were located, maturity of seed was monitored, and all seed was collected by hand. The taller grasses and forbs were harvested with a small sickle, while the lower growing species were harvested with scissors. Yearly fluctuations in weather affected seed ripeness, and during some years there were complete crop failures when seeds did not mature.

An Interagency Agreement with the Natural Resources Conservation Service was initiated in 1987 to assist us with seed management. After our seed was collected in the Park, it was accessioned, dried, and sent to the Plant Materials Center in Bridger, MT. The Bridger staff provided seed cleaning, testing, and storage as well as technical expertise in species selection and collection. Some seed was returned to the Park for direct seeding or propagation into containerized plant material. The remaining seed was stored or sent to private contractors for propagation or planted for seed production.

We estimated that collection costs ranged from \$25 per lb to \$500 per lb for Glacier's native seed, depending on the species. The Logan Pass project required a total of 18 lb of grass, carex, and forb seeds for seeding and another 16 lb of seed for plant production. Our seeding rates for grasses were 70 seeds per ft², which translated to an average of 20 to 25 lb of seed per acre. Seeding rates for Logan Pass were considerably higher at 120 seeds per ft².

Salvage of Plants and Soil

On each project we salvaged as much plant material and soil as possible prior to disturbance. Plants were salvaged in clumps, as whole shrubs and small trees, and as sod mats in prairie or subalpine meadow situations. This plant material was either 'heeled-in' onsite in a protected environment or held in our native plant nursery until construction was completed. We stored several thousand square feet of salvaged subalpine sod in planter boxes onsite for periods of 1 to 3 years with no measurable mortality.

We salvaged topsoil prior to construction to capture the native seed and propagule bank present in the soil. In some instances, this topsoil was moved to the top of the cut and pulled back down after construction was completed. If this was not possible, soil was stored in windrows of no more than 4 ft in depth, and replaced the same season to ensure the viability of the soil and seed once it was replaced.

Where there were not sufficient quantities of salvaged topsoil available, we considered soil importation. Inspections were made of soil sources to determine seed bank species and to prevent occurrence of invasive weed seeds. Laboratory analyses were made to determine texture and chemical compatibility with native soils. In the pristine subalpine environment at Logan Pass, the soil was very shallow, and we had a deficit of soil available for revegetation following construction. In this case, imported soil was pasteurized to prevent the introduction of any exotic plant material. It was necessary to import 450 cubic yards of pasteurized soil media for the Logan Pass project. This material consisted of 25 percent well-rotted sawdust, 25 percent sphagnum peat moss, 10 percent sand, and 40 percent

loam soil. This media was heated to 180 degrees for 30 minutes to ensure pasteurization.

Production of Plant Material

Plant Materials Center

Some of the seed that was sent to the Bridger Plant Materials Center was planted for seed production and harvested to provide increased quantities of pure, live seeds for each construction project. Shrubs were grown in production beds as bareroot planting stock. Propagation methods were tested on species that were difficult to grow to improve production.

Native Plant Nursery

A small native plant nursery was constructed at the Park Headquarters area in 1987 to develop propagation procedures for native plant species that were not commercially available at that time. The purpose of this facility was to develop propagation techniques, produce plant material from seed and cuttings, serve as a staging area for revegetation efforts, and provide educational opportunities for staff, public, and cooperators. With a new road project scheduled every 2 years, we managed a number of projects at the same time in various stages of planning, design, and construction. We needed the nursery for coordination of plant material demands on multiple projects over 20 years. We improved efficiency with shared resources, responded quickly to changing revegetation needs, and produced small quantities of species that met strict genetic specificity requirements.

By the end of the 1997 season, we provided a wide variety of plant species and size classes for individual road projects. The transplants had exceptionally high survival, with an average of 80 percent survivorship in our monitoring plots. In 1996, we were holding over 50,000 plants in our nursery facility in preparation for the Logan Pass restoration project. We produced an average of 25,000 plants per year for revegetation needs on the Going-to-the-Sun Road.

The planting plan prescribed approximately 55,000 plants for the Logan Pass project. These plants were propagated by the Bridger Plant Materials Center, the Park's native plant nursery, and private growers. In addition, a private grower was contracted to propagate plant-specific mycorrhizal fungi and to inoculate 30,000 containerized plants prior to delivery to Glacier National Park. The Bridger Plant Materials Center supplied an average of 2,000 bareroot shrubs annually and also grew some of the more difficult species to propagate in their greenhouse.

Greenhouses

In 1993, we received a grant that served as seed money for the construction of a small greenhouse at a local high school and for development of an educational outreach program for 5th- through 12th-grade biology students. The facility was completed with additional moneys and supplies donated by community members and local businesses. Each year approximately 6,000 plants were produced

in the greenhouse. Students collected seed at the Park in the fall, propagated containerized plants throughout the winter, and planted the material in the spring. Over 60 classes and nearly 1,000 students have participated in this innovative program. Additionally, our facility provided resource education to many visitors and students who toured and volunteered to work in the nursery.

Construction operations were initiated for two other greenhouse facilities in 1997. A hoophouse was located at the native plant nursery specifically designed as a weed-free enclosed growing environment for production of subalpine and alpine species. There were needs identified during the Logan Pass project to produce pallets of sod for projects in sensitive environments where it was critical to exclude exotic plants from the planting media. Also, funding was secured for a cooperative greenhouse at the Blackfoot Community College as a joint venture to produce plant material for revegetation projects on Blackfoot Tribal Lands and Glacier National Park.

Planting Strategies

The revegetation crew consisted of four crew members and a crew supervisor. They worked 10 hour days, 4 days a week from early May through October. Although they often faced difficult work conditions, these people were extremely motivated, hard working, and believed in the importance of their work. Leadership of the crew leader was critically important to achieve the restoration objectives. During the Logan Pass project, this crew was assisted in their work by a six-person crew from AmeriCorps Montana Conservation Corp. The short planting window at Logan Pass of mid July to early September, and the large number of plants to be installed, necessitated a larger planting crew.

Successful implementation of restoration work required careful coordination between planning, design, construction, and supervisory personnel. Comprehensive revegetation plans and planting designs were developed based on years of extensive site analysis and evaluation. These revegetation plans specified the needed plant materials by planting unit, supplies and equipment, soil strategies, personnel requirements, and sequencing of work activities. Considerations of visitor use, natural and cultural resource values, and historical record of construction along the road corridor was significant to revegetation planning.

One of the biggest coordination challenges was the tracking and moving of the large quantities of plant materials to the project sites. Plants were trucked daily from the nursery to the project sites to avoid mortality from desiccation and unpredictable weather conditions. Since the Going-to-the-Sun Road was kept open to visitor traffic during construction, the highly congested nature of the work site made access difficult. Thousands of plants had to be moved by hand or in wheelbarrows along busy roadways to reach individual planting units. Crew safety was always of greatest concern because of the need to work in proximity to large construction equipment and because of vehicle traffic on the extremely narrow road.

Revegetation efforts began immediately after the contractor finished final grading. Salvaged topsoil was pulled down over the new grade at an average depth of 2 inches.

In cases where imported soil was needed, the salvaged native soil was spread thinly over this imported material and mixed to make a more homogenous planting media and to inoculate the pasteurized material with indigenous soil microbes. At Logan Pass, a low-analysis (6:1:3) slow-release organic fertilizer was applied at a rate of 500 lb per acre over the site. A fertilizer was used in this instance because it was believed that this product would facilitate the recolonization of soil biota and enhance seedling establishment.

Seed was sown by hand prior to the installation of a biodegradable agronomy blanket composed of straw and coconut fiber woven with cotton string. Because of the high winds and extreme runoff from snowmelt the agronomy cloth was used to hold the seed and soil in place and to retain moisture. An overseeding of forb and carex species requiring light for germination was completed prior to the installation of containerized plant materials.

Landscape design was incorporated into the revegetation plan with written descriptions and drawings of how vegetation would be selected and arranged. Selections of species needed to be durable to vehicle and foot traffic, compatible with adjacent plants, and diverse in terms of texture of close-up and distant views. Plant material placement followed design guidelines, and wire flags were used to define locations of clumps of five to seven individual species. Despite the large quantity of plant material and variety of species, the adherence to planting plans was achieved.

Since we were dealing with cold-climate species, most revegetation was scheduled in the early fall or spring and discontinued between June 15 and September 1. Seeded areas were usually not irrigated, but relied on climatological patterns. At Logan Pass, irrigation was used the first 2 years to enhance establishment, vigor, and survivorship of planted materials. A low-tech passive irrigation system was developed in order to plant in July and August. An intake valve and over 1,000 ft of 2 inch plastic pipe were used to draw water out of two perennial streams with steep waterfalls. Simple valves and lengths of sprinkler hose delivered up to 8 gallons per minute of water to all planting units.

With completion of the planting, a significant challenge was to protect the newly established vegetation from being trampled by the nearly two million visitors traveling on the Going-to-the-Sun Road. Signs were placed at the sites to inform visitors of the restoration efforts. Within the concentrated Logan Pass Area we installed an unobtrusive and easily maintained chain barrier around all planted areas. Uniformed staff monitored and enforced the posted areas.

Monitoring Strategies

Assessment of Results

The Revegetation Monitoring Program was established in 1991 to provide baseline data for revegetation planning and assessment of results. The program helped evaluate completed revegetation work and helped determine whether objectives for restoration were met. Monitoring has been applied to seven road projects at Glacier National Park. This data was used to determine future strategies, to project trends over time, and to improve our revegetation methodologies. Monitoring results led us to conclude that

our revegetation methods were appropriate to achieve most of our goals and objectives. Results of monitoring data were documented in annual reports.

Monitoring strategies included establishing permanent transects on each plot that were used for line-intercept cover measurements of shrubs and trees. Canopy cover of all native and exotic plants and ground cover were measured in microplots along each transect (Asebrook and others 1996). Life form canopy cover estimates for each microplot were recorded as well. Ocular estimates were done in conjunction with microplot monitoring. Nested frequency monitoring was done where appropriate. The objective of each monitoring technique was to obtain sufficient data to provide for robust statistical comparisons.

Lake McDonald Section

The trend on these plots has shown that seeding native grasses and forbs resulted in higher native cover and lower exotic cover. Seeded plots had significantly higher native grass cover and significantly lower exotic forb cover than unseeded plots since monitoring began in 1992. Shrub survival remains high at 85 percent. This data suggested that revegetation should continue on these roadside areas, instead of relying on natural regeneration, for restoration of native communities (Asebrook and others 1996).

St. Mary to Rising Sun Section

Seeding native species along the roadcut resulted in a significant native component. On steep slopes, native grasses dominated the sites, and there was little erosion evident. Planted material had better survival and vigor when planted in spring rather than in the fall. Overall plant mortality increased on the revegetation plots over time, but there was still 60 to 70 percent survival of planted shrub species. Native grasses and shrubs showed the most success at controlling the dominance of exotic plants, but exotic species continued to be long-term components of the roadside communities (Asebrook and others 1997). Although exotic forb cover decreased, exotic grass cover dominated some roadcuts. It appeared seeding was necessary to introduce a native grass component to roadsides with salvaged soil to compete with exotic grass and forbs.

Logan Pass Section

Data collected the first year suggested that the survival of grasses was greater than 90 percent and survival of forbs and shrubs was greater than 80 percent. Of the live plants evaluated, greater than 90 percent had a vigor rating of good/fair (Asebrook and others 1997). Initial data supported the use of fertilizer treatments because the treated areas showed greater cover of seeded material, particularly grass germinants. Additional evaluations helped us determine if our seeding rates were appropriate, and if only seeding would have been as effective at reestablishing vegetation over time as the more costly and time-consuming planting and seeding.

Conclusions

The restoration of native plant communities removed during new construction was part of the Federal Lands Highway Program to rehabilitate the Going-to-the-Sun Road. The methods that were used included the preconstruction inventories, extensive planning, collection of seed and cuttings, propagation of containerized and bareroot material, increase of seed, and planting of grass, forb, shrub, and tree species. The success of these strategies depended on people with diverse disciplines working together and learning from their experiences. Although costly, results have shown we can achieve quality park roads, quality park experiences for visitors, and preservation of cultural and natural resources. Over the years we have developed a working relationship through partnerships and teamwork to assure that the Going-to-the-Sun Road will continue to provide access to the Park consistent with sustaining the world class quality of the natural and cultural resources of Glacier National Park.

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