National Park Service
U.S. Department of the Interior

Crater Lake National Park

Rim Drive Rehabilitation Revegetation Project

2020 Annual Report

ON THIS PAGE
Collecting pine lupine (*Lupinus albicaulis* var. *shastensis)* seed along East Rim Drive.
Photo by Carrie Wyler.

ON THE COVER
A roadside wildflower display along East Rim Drive.
Photo by Carrie Wyler.

Rim Drive Rehabilitation Revegetation Project

2020 Annual Report

Carolyn S. Wyler, Scott E. Heisler, and Jennifer S. Hooke

National Park Service
Crater Lake National Park
P.O. Box 7
Crater Lake, Oregon 97604

April 2021

U.S. Department of the Interior
National Park Service
Crater Lake National Park
Crater Lake, Oregon

This annual report series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by a subject matter expert who was not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Crater Lake National Park website at:

https://irma.nps.gov/DataStore/Reference/Profile/2285261

Please cite this publication as:

Wyler, C.S., S.E. Heisler, and J.S. Hooke. 2021. Rim Drive Rehabilitation Revegetation Project: 2020 Annual Report. Crater Lake National Park, Crater Lake, Oregon.

April 2021

Contents

Figures

Page

Tables

Page

Abstract

Crater Lake National Park's Rim Drive Rehabilitation Revegetation project aims to mitigate impacts to the rim environment from the Federal Highway Administration-sponsored Rim Drive Rehabilitation project. This major construction project is correcting many deficiencies present along the Park's historic Rim Drive and has been split into "Phases" encompassing iterative work progression. Phase I of this project has been completed and revegetation work for Phase II commenced in the 2020 season. Through developing revegetation prescriptions, surveying for and controlling invasive plant species, salvaging and reestablishing rare plant populations disturbed by the construction project, and restoring disturbed areas using site-specific native plants and seed it is hoped that long-term impacts from this construction project to the Park's natural resources will be minimized. During the 2020 field season, 42,156 invasive plants were removed from the project area. Revegetation prescriptions were completed for 21 newly identified restoration sites for Phase II. Plant materials were collected from five distinct seed zones representing the floral diversity of the Phase II project area. Forty-three seed accessions were provided to the USFS Dorena Genetic Resource Center for cleaning. Documentation was refined for each disturbed site to inform future restoration efforts and assess revegetation efficacy. In 2020, Crater Lake National Park staff outplanted 1,633 native plants and dispersed 5,463 grams of native seed throughout areas disturbed by Phase I of the project.

Acknowledgments

The Crater Lake National Park Maintenance staff allowed use of the Ball Diamond and South Yard staging areas for storage of plant materials and related infrastructure. Kirsten Hardin, Helen Oppenheimer, Jennifer Corwin, and Jennifer Longmire assisted with translating construction plans and schedules into tangible restoration goals and timelines. Assistance with planting and seeding was received from members of the Crater Lake National Park Botany staff, especially Hamilton Hasty, Eleanor Roeder, Shaina Nicassio, and Shane Palmer. The Meeker Plant Materials Center maintained fields for seed increase efforts and stored seed. The U.S. Forest Service Dorena Genetic Resource Center aided with seed cleaning and storage.

Introduction

The Federal Highway Administration (FHWA)-sponsored Rim Drive Rehabilitation and Rockfall Mitigation project is a multi-year endeavor to enhance and improve Crater Lake National Park's (CRLA) historic and scenic Rim Drive and its associated pullouts and parking areas. The 29.4-mile-long Rim Drive is a popular Park road and destination; it provides seasonal access to the caldera rim with its many trailheads and scenic vistas of Crater Lake and the surrounding Cascade Range. Rim Drive is listed on the National Register of Historic Places and has been nominated as a cultural landscape. Rim Drive was completed in 1941, and occasional repairs have occurred in the years since its construction. However, major reconstruction is now occurring as existing roadway materials have exceeded their lifespan, and the roadbed and associated masonry features have deteriorated due to erodible soils and years of harsh weather.

Phase I of the Rim Drive Rehabilitation project was initiated in 2014 and focused on rockfall mitigation and road rehabilitation along Rim Drive. In 2015 road rehabilitation work affected six miles of West Rim Drive, portions of East Rim Drive (e.g., North Junction to Cleetwood Cove; Skell Head; Grotto Cove), and the Rim Village parking lot. Major construction work on Phase I was completed in November 2018. Several new (i.e., unplanned disturbance) revegetation areas were established in 2016, 2017, and 2018 along West and East Rim Drives resulting from activities such as deep patch work, road realignment, and correcting drainage issues. Phase II will complete the remainder of the Rim Drive Rehabilitation project, starting at Cleetwood Cove and heading clockwise around the rim to Park headquarters. Revegetation work for Phase II commenced in 2020, and construction work is slated to begin during summer 2022. Phase II construction plans have identified major deep patch and edge stabilization areas along the roadway, which allows for better revegetation planning and preparation. In addition to impacting roadways and road shoulders, numerous pullouts, parking areas, and parking lots have been and will be modified. A master list of planned revegetation sites for Phase II that will need restoration is in Appendix A, and a map of site locations is displayed in Figure 2. These modifications include obliterating unofficial pullouts (Figure 3), shrinking the footprint of excessively large parking areas (Figure 1), and installing landscaping islands in high visitor use areas.

Figure 1. Example of an excessively wide parking area within the project area. Photo by Jen Hooke.

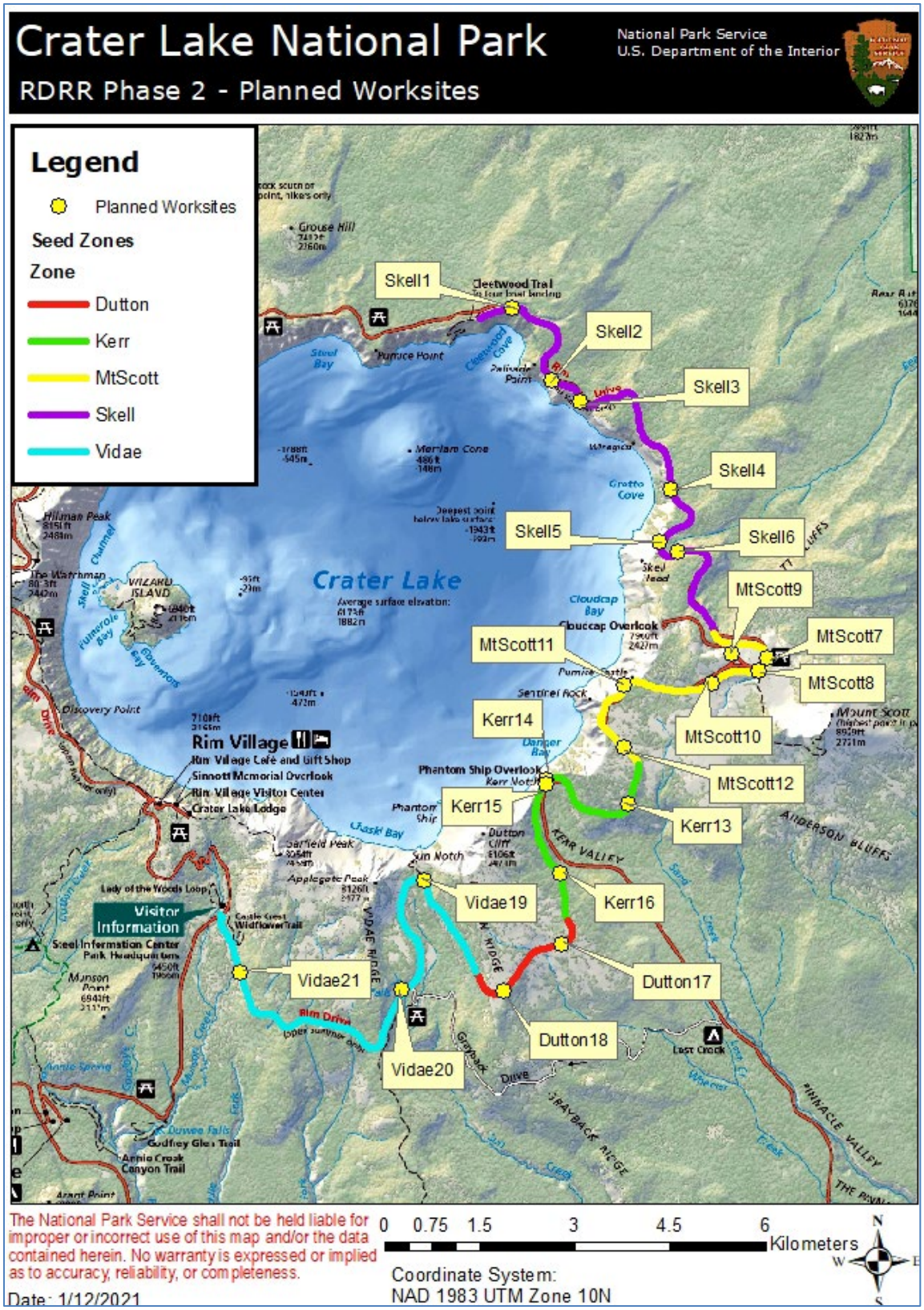

Figure 2. Map of planned disturbance and restoration sites by seed zone for Phase II of the RDRR project. Map by Carrie Wyler.

Figure 3. User-created pullouts before (left; photo by Carrie Wyler) and after (right; photo by Scott Heisler) obliteration as part of the Rim Drive Rehabilitation project.

Additionally, road work has and will affect numerous rare and/or sensitive plant species within the project area. Construction during Phase I displaced the world's largest known population of the Crater Lake rockcress (*Boechera horizontalis*), a rare plant that is considered a Species of Concern by the United States Fish and Wildlife Service, and a candidate species for listing as threatened or endangered by the state of Oregon.

Due to the substantial impacts occurring to soils and vegetation, FHWA funded efforts to restore affected areas through revegetation, special status plant species management, and invasive vegetation management. The Rim Drive Rehabilitation Revegetation (RDRR) project is tasked with:

1. Developing revegetation prescriptions for disturbed areas to be restored.
2. Surveying for and controlling non-native, invasive plant species within the project area.
3. Salvaging, transplanting, and monitoring special status plants impacted by the project.
4. Collecting native plant seed and materials for revegetation efforts.
5. Restoring affected areas through site preparation, planting, and seeding.
6. Monitoring restored areas for revegetation efficacy and augmenting restoration actions.

Restoration of areas disturbed by the Rim Drive Rehabilitation project (Figure 4) is necessary to jumpstart natural succession of vegetation communities, protect the rim environment from soil erosion, and prevent invasion by non-native plant species. Through using site-specific, native genotypes in revegetation efforts, the biodiversity and genetic integrity of the rim vegetation community is maintained. Additionally, as Rim Drive is a popular Park road, revegetation will yield aesthetic benefits to Park visitors by reducing the appearance of bare, disturbed ground throughout the project area.

Figure 4. Conducting restoration outplantings (left) and collecting seed (right) for the Rim Drive Rehabilitation project. Photos by Carrie Wyler.

The 2020 field season focused on documenting restoration site prescriptions, gathering plant materials, and commencing plant propagation. Six seasonal Biological Science Technicians (Plants) were partially funded by the RDRR project in 2020; season length was from May 26 – September 30. The Covid-19 pandemic affected the field season by reducing the number of employees devoted to completing project work. This resulted in fewer plant materials and seed gathered and less intensive invasive plant survey and control work. These shortfalls will need to be compensated for in future years.

Methods

Efforts made by the Botany program in 2020 can be organized into three components: (1) revegetation; (2) special status plant management; and (3) invasive vegetation management; these are described below.

Revegetation

Site Prescriptions

Prior to construction, revegetation prescriptions were developed for each area slated for restoration. These prescriptions serve to document the pre-disturbance site features and plant community composition unique to each area. Prescriptions were developed by making visits to each site and recording the dominant plant species with an ocular estimate of each species' relative cover. This documentation was established to inform revegetation efforts by providing a baseline from which to determine the number of plants and amount of seed to be used at each site. Sometimes unanticipated disturbance results from construction; in these instances, *ex post facto* restoration prescriptions are developed from adjacent undisturbed plant communities and the restoration is deemed an "unplanned" site. For most planned sites, photo points were established, and photos were taken of each pre-disturbance site. Revegetation prescriptions are housed on the Botany file server at Park

headquarters. The specifics of this process are outlined in a project-specific Revegetation Plan (Gregory et al. 2015).

Seed Collection

The project area was delineated into seed zones, with each zone serving as a distinct area where seeds and propagated plants could be sourced and moved without compromising genetic integrity. In defining seed zones, sites with similar vegetation communities were grouped together - these groupings corresponded to similarities in site location and elevation. Five seed zones were defined for Phase I of the RDRR project:

- South West Rim Drive (South WRD)
- Central West Rim Drive (Central WRD)
- North West Rim Drive (North WRD)
- Northwest East Rim Drive (NW ERD)
- Northeast East Rim Drive (NE ERD)

Five seed zones (Figure 2) were defined for Phase II of the project based on the same Phase I parameters and named for prominent features in those areas:

- Skell
- Mt. Scott
- Kerr
- Dutton
- Vidae

Once seed zones were delineated, a discrete revegetation species list for the project was developed. In order to develop cost-effective agreements and work plans between CRLA and the partners with responsibility for seed cleaning, seed storage, and plant propagation for this project, it has been found that using eight to ten plant species (accessions) per seed zone is adequate for revegetation efforts. Species substitutions and species additions are made as necessary to help fill any gaps in the species accession list. The Corvallis Plant Materials Center (PMC) provided seed cleaning and plant propagation services to CRLA in Phase I; and the U.S. Forest Service Dorena Genetic Resource Center (DGRC) is assisting CRLA with initial seed cleaning and plant propagation for Phase II of the RDRR project.

Since the inception of Phase I of the RDRR project, CRLA has developed the capacity to clean and propagate a limited selection of plant species in-house. While maintaining eight to ten accessions per seed zone is still abided by when dealing with Park plant materials partners, additional plant species have been included for Phase II seed zones that will be cleaned and propagated at the Botany program's native plant nursery at the Ball Diamond staging area at Park headquarters. The core eight to ten accession species are designated as "priority" seed collection species (Table 1).

Denver Service Center (DSC) staff recommends collecting large quantities of seed from abundantly occurring species, as custom seed mixes can be supplemented with excess seed that can also be available to accommodate unanticipated disturbance areas. As per the "Seed Collection in National Parks" manual (Taliga et al. 2015), seed is collected ideally from 30 - 100 individual plants per population, taking care not to collect more than 20% of seed from the total population unless it is

slated for removal due to construction, in which case as much seed as possible should be collected. During the 2020 field season, no seed was collected for Phase I, and seed collection commenced for Phase II (Table 1).

Table 1. 2020 seed collection list per seed collection zone. * = Denotes priority seed collection species.

ZONE	PLANT TAXA (Scientific name, common name)	
Skell	*Eriocoma occidentalis** --western needlegrass	*Juncus parryi** --Parry's rush
	*Calyptridium umbellatum** --pussypaws	*Linanthus pungens* –granite gilia
	*Carex pachycarpa** --many-rib sedge	*Lupinus albicaulis* var. *shastensis* –pine lupine
	Ceanothus prostratus var. *prostratus* –Mahala mat	*Lupinus lepidus* var. *lobbii** --prostrate lupine
	Diplacus nanus –dwarf monkeyflower	*Oxyria digyna* –mountain sorrel
	*Ericameria greenei** --Greene's goldenbush	*Packera cana* –wooly groundsel
	Ericameria nauseosa var. *speciosa** --showy rabbitbrush	*Penstemon speciosus* –royal penstemon
	Eriogonum ovalifolium var. *nivale* –cushion buckwheat	*Phacelia hastata* var. *compacta** --compact phacelia
	Holodiscus microphyllus var. *glaberscens** --bush ocean spray	*Purshia tridentata* –antelope brush
	Ipomopsis congesta var. *palmifrons* –palm leaf ballhead gilia	
Mt. Scott	*Eriocoma occidentalis** --western needlegrass	*Eriogonum pyrolifolium var. coryphaeum* –alpine buckwheat
	Aconogonon davisiae var. *davisiae** --Davis' knotweed	*Eucephalus ledophyllus* –Cascade aster
	Alnus alnobetula ssp. *sinuata* –Sitka alder	*Hulsea nana* –dwarf Hulsea
	Boechera howellii –Howell's flatseed rockcress	*Juncus parryi** --Parry's rush
	*Calyptridium umbellatum** --pussypaws	*Lomatium martindalei* –Cascade desert parsley
	Castilleja applegatei var. *appelgatei* –Applegate's paintbrush	*Lupinus lepidus* var. *lobbii** --prostrate lupine
	Dieteria canescens var. *shastensis* –rayless Shasta aster	*Penstemon davidsonii* var. *davidsonii* –Davidson's penstemon
	*Ericameria greenei** --Greene's goldenbush	*Phacelia hastata* var. *compacta** --compact phacelia
	Eriogonum marifolium var. *marifolium** --Sierra eriogonum	
Kerr	*Eriocoma occidentalis** --western needlegrass	*Erigeron glacialis* var. *glacialis* –peregrine fleabane
	Aconogonon davisiae var. *davisiae** --Davis' knotweed	*Eriogonum marifolium* var. *marifolium** --Sierra eriogonum
	Ageratina occidentalis –western boneset	*Eriogonum nudum* var. *nudum* –barestem buckwheat
	Alnus alnobetula ssp. *sinuata* –Sitka alder	*Holodiscus microphyllus* var. *glaberscens** --bush ocean spray
	Arnica cordifolia –heart-leaved arnica	*Juncus parryi** --Parry's rush
	Arnica longifolia –longleaf arnica	*Lomatium martindalei* –Cascade desert parsley
	*Calyptridium umbellatum** ---pussypaws	*Lupinus albicaulis* var. *shastensis* –pine lupine

ZONE	PLANT TAXA (Scientific name, common name)	
	Carex species*	*Lupinus lepidus* var. *lobbii** --prostrate lupine
	*Drymocallis glandulosa** --sticky cinquefoil	*Pentstemon rupicola* –cliff penstemon
	Elymus glaucus ssp. *glaucus* –blue wildrye	*Phacelia hastata* var. *compacta** --compact phaceila
	*Ericameria greenei** --Greene's goldenbush	
Dutton	*Eriocoma occidentalis** --western needlegrass	*Eriogonum marifolium* var. *marifolium** --Sierra eriogonum
	Aconogonon davisiae var. *davisiae** --Davis' knotweed	*Eriogonum nudum* var. *nudum* –barestem buckwheat
	Anemone occidentalis –western pasqueflower	*Eriogonum pyrolifolium* var. *coryphaeum* –alpine buckwheast
	*Calyptridium umbellatum** --pussypaws	*Eucephalus ledophyllus* –Cascade aster
	Castilleja species	*Juncus parryi** -- Parry's rush
	Chaenactis alpine –alpine chaenactis	*Lupinus lepidus* var. *lobbii** --prostrate lupine
	Dieteria canescens var. *shastensis* –rayless Shasta aster	*Phacelia hastata* var. *compacta** --compact phacelia
	*Ericameria greenei** --Greene's goldenbush	*Raillardella argentea* –silky raillardella
Vidae	*Eriocoma occidentalis** --western needlegrass	*Eriogonum marifolium var. marifolium*--Sierra eriogonum*
	Aconogonon davisiae var. *davisiae** --Davis' knotweed	*Eriogonum pyrolifolium* var. *coryphaeum* –alpine buckwheat
	Anemone occidentalis –western pasqueflower	*Erythranthe lewisii* –great purple monkeyflower
	*Calyptridium umbellatum** --pussypaws	*Holodiscus microphyllus* var. *glaberscens** --bush ocean spray
	Carex halliana –Hall's sedge	*Juncus parryi** --Parry's rush
	*Carex pachycarpa** --many-rib sedge	*Lupinus albicaulis* var. *shastensis* –pine lupine
	Castilleja species	*Lupinus lepidus* var. *lobbii** --prostrate lupine
	Elymus glaucus ssp. *glaucus* –blue wildrye	*Penstemon davidsonii* var. *davidsonii* – Davidson's penstemon
	*Ericameria greenei** --Greene's goldenbush	*Phacelia hastata* var. *compacta** --compact phacelia
	Erigeron glacialis var. *glacialis* –peregrine fleabane	*Senecio triangularis* –arrowleaf groundsel

The seed collection process commenced in 2020 by observing and documenting the phenology of each priority targeted species at each revegetation site within each seed zone in Phase II. Notes were taken on plant phenology, seed maturity, and collection techniques; these observations helped refine seed collection protocols for each species (Beck et al. 2017). A map was developed for all seed collection locations in each seed zone (Figure 2).

When seeds were mature, they were collected, dried, and stored until shipment to the DGRC. Within each zone a single bag was used to collect all the seed from an individual species (Figure 5). In the field, bags were labelled with species code, collection date, and seed zone. After collection, seeds were transported to the seed drying and storage facility in the Stall Nine garage at Park headquarters (Figure 5). When seeds arrived at this facility, records were kept for each species with collection

dates, specific collection location, and seed zone. Seeds were then placed inside 30-gallon plastic storage totes secured with window screen at the top, allowing ventilation while reducing chances of predation. Plant species with very small seeds were first placed in smaller plastic bins before being stored within the larger 30-gallon tubs (Figure 5). The bins were labelled and organized on shelves by seed zone and species. Damp collections (especially lupines) were either shipped soon after collection (within a week) or set out in the sun during the day to speed the drying process.

Prior to shipping seed to the DGRC, all seeds from a single species within a discrete seed zone were combined into doubled paper bags; each bag was labeled with species code and seed zone and taped shut. Records were kept of boxes shipped and their contents. Shipping seeds throughout the growing season was crucial due to the shortage of seed storage space at the Park, and inadequate ventilation for effective drying of damp material.

Figure 5. Seed drying and storage facility at Park headquarters (left). Collected seed before cleaning (middle). Seed drying in a container inside a drying bin with ventilated lid (right). Photos by Carrie Wyler.

Plant Care and Nursery Work

Due to delays in the construction schedule, planting for Phase I was not completed in the fall of 2019 and several thousand plants needed to be overwintered at the Ball Diamond nursery at Park headquarters. These plants required care and maintenance throughout the 2020 field season. Once the snow melted in June, plants were covered with a shade house (40' x 20' x 10' – Figure 6).

Figure 6. Overwintered plants emerging from the snow in the spring (left). Shadehouse at the Ball Diamond (right). Photos by Carrie Wyler.

The plants were fertilized with Osmocote 14-14-14 slow release fertilizer. Fertilizer was applied at the beginning of the season when plants emerged from the snow at a rate of ¼ tsp per planting tube. Descriptions of fertilization procedures can be found in Botany program files in the "Nursery Activities" binder. Excess growth was manually trimmed with scissors or clippers as needed. Any reproductive structures were removed to promote root development and prevent excess evapotranspiration, and dead growth was removed to discourage fungal growth. Undesired plant volunteers originating from Corvallis PMC in the planting tubes (e.g., moss, liverworts, and weeds) were removed before planting to minimize the risk of introducing non-native species to the Park. Any excessively root bound plants, including many grasses, sedges, spreading phlox (*Phlox diffusa*), and manzanita (*Arctostaphylos* sp.), were transplanted into larger containers or divided. The full details of which plants were transplanted can be found in the "Nursery Activities" binder at Park headquarters.

Despite a successful planting season, some Phase I plants are being held over the 2020-21 winter at the Ball Diamond to fill in gaps as needed during the 2021 season. When ambient temperature dropped below freezing the containers were consolidated and mulch was stacked around the bases of herbaceous plants to prevent root freezing (Figure 7). These plants will need further care in the summer of 2021 including watering, fertilization, and transplanting into larger containers. All remaining Phase I plants should be outplanted by fall 2021.

Anticipating the need for established containerized plants for use in Phase II and the slow growth of native plants in the high elevation conditions at CRLA, an advance round of plant propagation was conducted at CRLA in fall 2020. A method of plant propagation previously established by the Botany program was utilized to address staffing and equipment limitations (Heisler et al. 2019). This method uses the reliable snowpack at CRLA for cold stratification of pre-seeded pots. Selection of plant species and quantities for this effort were based upon the program's familiarity with the project area and experience gained from Phase I of the project.

Additional difficult-to-propagate plant material needs for this project will be predominantly sourced through an interagency agreement with the DGRC.

Figure 7. Distributing mulch around the edges of pots to insulate against frigid winter temperatures (left). Consolidated plants at the Park's Ball Diamond prior to overwintering (right). Photos by Carrie Wyler.

Site Preparation

Prior to planting or seeding a disturbed site, efforts are made to prepare the site for restoration. This entails ensuring the soil has been sufficiently decompacted, making certain the slope and appearance of the disturbed site blends in with the natural topography and appearance of the area, and smoothing out any vehicle tracks, berms, or other unnatural depressions at the site. Soils are amended with Park-sourced woody debris, compost, forest litter, and duff.

The Botany program creates compost from discarded vegetative materials resulting from Park maintenance activities; these compost piles are located in the Park's South Yard to capitalize on its lower elevation location. Compost temperature is monitored over the season to ensure the presence of active biota (Figure 8). Compost is used to provide a source of natural fertilizer and mulch for newly planted seedlings. Compost also helps create local microclimates, retain soil moisture, and provide microfauna to help promote soil development and aid the establishment and growth of young plants. Woody materials are also used to help stabilize recently disturbed and denuded sites from road construction while creating microclimates and seed pockets to further encourage the natural recovery of disturbed areas. Larger woody debris (branches, logs, etc.) is obtained from the surrounding forest at disturbed sites and added to restoration sites as appropriate to assist with erosion control and site amelioration.

Figure 8. Compost being hauled from the Pole Bridge Quarry pile to the South Yard pile for use in restoration projects (left). Active biota in the Park-made compost (right). Photos by Carrie Wyler.

Planting and Seeding

A mix of plant species was planted in the Phase I disturbance areas in accordance with revegetation prescriptions and availability of plant materials. After planting, compost was added, and plants were watered (Figure 9). Site-specific seed mixes were prepared and hand-broadcast over planted areas, and across areas with slopes that were too steep to plant. After broadcasting seeds, the sites were scarified with hand rakes and compost was broadcast over the scarified areas.

Figure 9. Planting in disturbed sites along West Rim Drive (left). Watering plants after restoration planting (right). Photos by Scott Heisler.

At restoration sites, holes were dug to a depth equal to or greater than the length of the planting tubes. Plants were carefully removed from the tubes by pressing on the sides of the tubes or tapping the rim of the tubes while they were inverted over the planting holes. After the plants had been removed, the roots were inspected for any signs of being root bound, having roots growing upward in the tube ("J"-rooting), or root girdling. If any of these were found, the roots were either trimmed or gently teased apart to encourage root growth and plant establishment. The plants were then placed in planting holes to ensure they were upright perpendicular to the pull of gravity (not relative to the local topography). Soil was then pushed back into the planting holes and tamped down gently to remove any air pockets in the soil. Plantings were installed so that the root collars of the plants were just at or slightly below the surface of the soil. Remaining soil or additional soil from the surrounding area was used to create a berm wall around the plants to facilitate water retention and help stabilize and protect plants. One or two handfuls of compost were then placed in the center of the rings around plants (Figure 10). After mulching, the plants were watered at least once. A 200-gallon water tank was mounted in the bed of a truck and used in conjunction with an electric pump to facilitate watering of newly planted plugs (Figure 10).

Figure 10. Building a berm for a plant (upper left). Recently installed plants with compost and soil berms to contain water (upper right). The 200-gallon truck-mounted water tank (bottom). Photos by Carrie Wyler.

Site Documentation and Monitoring

The restoration process for each site was documented using monitoring forms and photo points. Sites restored prior to 2020 were monitored by making ocular assessments of the survival of planted species and the degree of vegetation establishment and recovery. Any additional planting and/or seeding needs for the site were noted. These assessments are completed annually in order to track the progress of revegetation efforts. For sites planted in 2020, data were recorded on the number and species of plants outplanted, the weights and species of seed broadcast, and any natural litter/woody debris that was placed at the site. For planned restoration sites with previously established photo points, photos were repeated prior to planting, or just after planting, in order to document the appearance of the site post-disturbance relative to pre-disturbance. For unplanned sites, new photo

points were developed, and photos were taken prior to planting. Repeat photo points are taken and sites are monitored once a year for three years following revegetation efforts in order to monitor the status of vegetation recovery. Data are maintained for each restoration site containing the site prescription, photo points, and monitoring forms. These files are kept in site documentation binders in the Botany office and are also located on the Botany server.

Special Status Plant Management

In the process of rehabilitating Rim Drive and implementing rockfall mitigation, many special status plant populations growing adjacent to Rim Drive have been or will be impacted. This includes populations of rare plants such as Shasta arnica (*Arnica viscosa*), pumice moonwort (*Botrychium pumicola*), Crater Lake rockcress, a currently undescribed species of rockcress (*Boechera* undescribed), and shaggy hawkweed (*Hieracium horridum*). Phase I construction displaced populations of the Crater Lake rockcress and Shasta arnica (Figure 11). All of these species are present in higher numbers in the Phase II project area and impacts are expected.

Figure 11. Crater Lake rockcress (left) and Shasta arnica (right). Photos by Jen Hooke.

Five-needle pine species (Figure 12) are declining throughout their ranges due to their susceptibility to the disease white pine blister rust, caused by the non-native fungal pathogen *Cronartium ribicola*. Two five-needle pine species occur within the road prism of the project area: whitebark pine (*Pinus albicaulis*) and western white pine (*Pinus monticola*). The U.S. Fish and Wildlife Service has recently proposed listing whitebark pine as a threatened species under the Endangered Species Act; western white pine is a CRLA species of management concern. To better protect these iconic trees against impacts from construction activities, a survey of five needle pine species was conducted in areas where high levels of roadside disturbance were anticipated. This survey provided precise

locations of these species for incorporation into project plans and serves as a monitoring reference for the CRLA Botany program.

Figure 12. Whitebark pine (left) and western white pine (right). Photos by Jen Hooke.

The five-needle pine survey was conducted in July and August of 2020, guided by 70% construction design plans. The survey targeted areas of intense roadside disturbance including deep patch, edge stabilization, pavement obliteration locations, and pullouts/parking lots where equipment might be staged. Field data collection used Collector for ArcGIS and utilized a submeter Global Navigation Satellite Systems (GNSS) receiver with real-time Satellite-based Augmentation System (SBAS) correction (EOS Arrow 100).

Data collected for individual trees is detailed in Table 2. Geotagged photo points were also established for most mature trees in the survey, as well as for many saplings perceived to be at high risk. Several areas in the survey contained both whitebark and western white pines. A fixed 15 cm caliper gauge was used to assess diameter at breast height (DBH) to differentiate between overstory and sapling age classes. Dense clumps of trees sharing a common base area (a common growth pattern for whitebark pine) were recorded as a single point, with the number of stems noted. These clumps were assigned an age class based upon the largest stem. Observations of mountain pine beetle, white pine blister rust, and mechanical damage were made incidentally, and not as a focus of the survey. Potential threat level from construction activities was based on anticipated ground disturbance in the proximity of each tree and its roots. The extent of the surveyed area from the pavement edge was similarly judged, using areas receiving similar treatments disturbed during Phase 1 as a guide. The lengths of surveyed road prism were recorded by placing the GNSS receiver antenna directly above the driver door of a vehicle and recording a path as the length of road was driven. In addition to delineating the area surveyed, this line provided a rough landmark for the center of the road.

Table 2. Data collected for individual trees in the five-needle pine survey. Datum fields are the header row, with available inputs for a field listed in the column below.

Species	Age Class	Overall Health Category	Bark Beetle Damage Evident	Blister Rust Damage Evident	Mechanical Damage	Potential Threat from Construction
Pinus albicaulis	Seedling < 30 cm	Healthy	No	No	No	None
Pinus monticola	Sapling 30-130 cm	Sick/Struggling	Yes	Yes	Yes	Minor
	Mature Understory < 15 cm DBH			Suspect		High
	Mature Canopy > 15 cm DBH					

To mitigate impacts to the Park's special status plant species, baseline information is collected on pre-disturbance plant populations and seed is collected from rare plants for future propagation and revegetation efforts. Rare plant populations are mapped, and census data collected for each population. Wherever possible, special status plant species are protected from construction impacts. When impacts are unavoidable, rare plants are salvaged, cared for at a holdover facility, and transplanted back into their habitat post-disturbance. Additionally, supplemental planting of propagated rare plants is conducted, and reestablished populations are monitored to inform management. Extensive portions of East Rim Drive will be impacted by deep patch and edge stabilization work. These areas were surveyed for rare plants, and those encountered were documented with a submeter GNSS receiver using real-time SBAS correction (EOS Arrow 100).

Invasive Vegetation Management

Crater Lake National Park has assigned all its 91 non-native plant species a management priority of Low, Medium, High, or Watch. All high priority species are actively targeted for control efforts; medium priority species are targeted as time and resources allow. Low priority species are usually not targeted for management, either because populations of these species are not aggressively spreading, or populations are beyond control. Watch species are those that have been documented within the Park but have not been observed in some time (> 10 years) and are believed to be eradicated from within Park boundaries. If any watch species are found within the Park, they receive a management priority of high. These priorities may change depending upon situation and location. For example, most of the Rim Drive environment is relatively pristine and lacking non-native plant members. In this case, medium or low priority species may be treated in this area to protect the integrity of the vegetation communities adjacent to Rim Drive. Additionally, many rare plant species are found immediately adjacent to or nearby Rim Drive; low priority species may be controlled if they threaten rare plant populations.

The control strategies for invasive plants found within the RDRR project area are containment (preventing new infestations and spread); reduction (reducing the size and extent of existing infestations); and eradication (extirpating the invasive species from the Park). Since Rim Drive

contains relatively few invasive plants, invasive plant populations along Rim Drive and project staging areas often have reduction or eradication strategies. The strategy at Rim Village is containment, reduction, or eradication as this location has a persistent invasive plant problem.

In 2020, most of the project area was surveyed for non-native, invasive plant species. Roadsides were surveyed throughout the season by foot. Project staging areas (Roundtop Quarry, the Ball Diamond, Pole Bridge Creek Quarry, and the junction of East Rim Drive and Pinnacles Road) were surveyed at least once by foot in their entirety, including access roads and around piles of materials. Usually areas are surveyed two to three times per year in their entirety, but due to the Covid-19 pandemic, surveys occurred only once in 2020.

When invasive plants are encountered, data are recorded including scientific name, UTM coordinates (Zone 10, NAD83 datum), total number of plants present, area occupied by invasive plants, and treatment applied to population. Invasive plants are controlled via manual or chemical methods (Figure 13) as per the Park's Invasive Vegetation Management Plan (DOI NPS 2017). All plant parts capable of reproduction are bagged and disposed of in the trash compactor at Park headquarters. Vegetative parts incapable of reproduction are left to desiccate on site unless they present logistical or aesthetic problems for Park visitors, employees, and partners.

Figure 13. Manually controlling an invasive grass near Skell Head overlook (left). Chemically controlling St. John's wort (*Hypericum perforatum*) on East Rim Drive (middle). Chemically treating common dandelion (*Taraxacum officinale*) on a cliffside along East Rim Drive (right). Photos by Carrie Wyler.

Any new-to-CRLA non-native plant species encountered are collected as voucher specimens for the Park's herbarium. Additionally, non-native plants encountered in previously undocumented locations are collected for the Park's herbarium.

Results

Results are presented separately for each component of the RDRR project.

Revegetation

Site Prescriptions

As of November 2020, 62 restoration sites have been defined for Phase I and 21 for Phase II of the RDRR project, each with a unique revegetation prescription based on pre-disturbance conditions (Table 4). Identification of the Phase II restoration sites was guided by the 70% construction plan sets and did not include sites disturbed by Roundtop Quarry rehabilitation, deep patch, or edge stabilization treatments. It is likely the number of sites will increase as impacts from those treatments become more apparent. When Phase I of the Rim Drive Rehabilitation project was completed, the actual area disturbed was found to be greater than three times what was planned (Table 3). The planned area of disturbance for Phase II of this project is anticipated to affect 21.2 acres. Full details of each site's prescription and planned versus actual disturbance areas can be found on the Botany file server. Similar documentation will be made for Phase II of the project to track disturbed areas (Figure 14).

Table 3. Total planned versus actual disturbance areas for Phase I of the RDRR project.

Total Planned Disturbance Area	97,809 ft ^{2} (2.25 acres)
Total Actual Disturbance Area	301,137 ft ^{2} (6.96 acres)
Difference	**203,328 ft ^{2} (4.71 acres)**

Figure 14. Restoration site NEERD4 before (left) and after (right) rehabilitation and revegetation efforts. Photos by Carrie Wyler.

Table 4. Example of a site documentation form for the RDRR project.

Seed Zone: Dutton	**ID:** D17	**Planned site**
Location: Dutton Ridge, WBP tree pullout, non-lake side, (station 644+ to 646+)		
Site Description: gravel pullout to obliterate		
Pre-Disturbance Site Information		
Plant Species	**Common Name**	**Relative % Cover**
Aconogonon davisiae var. *davisiae*	Newberry's fleeceflower	5
Agoseris sp.	Agoseris	2
Calyptridium umbellatum	Pussypaws	3
Carex halliana	Hall's sedge	33
Castilleja arachnoidea	Cobwebby paintbrush	3
Ericameria greenei	Greene's goldenbush	15
Eriogonum marifolium var. *marifolium*	Sierra eriogonum	10
Grasses (*Elymus elymoides* ssp. *elymoides, Eriocoma occidentalis)*	Squirreltail, western needlegrass	15
Lupinus albicaulis var. *shastensis*	Pine lupine	2
Lupinus lepidus var. *lobbii*	Prostrate lupine	5
Phacelia hastata var. *compacta*	Compact phacelia	3
Viola purpurea	Goosefoot violet	2
Other		2
	Total Cover:	100%
Associated species: *Raillardella agenta* (silky raillardella), *Pinus albicaulis* (whitebark pine -- sensitive)		
UTM (Zone 10, NAD 83):	End: 0576025	End: 4749089
Total Vegetative Cover: 65%		**Elevation:** 7,204 ft.
Slope: low (–8 degrees)	**Aspect**: NW	**Snowmelt out:**
Soil "hardness," presence of rocks:		
General Soil description: pumice, sand, gravel 6: sand, gravely		
Ameliorating microsite features: duff, pine needles, sticks, gravel, 1: existing vegetation 5: fine organic debris		
Wind exposure: high	**Canopy cover (overall):** low-medium	
Area:		
Comments: Whitebark pine clump at site		
Recorder: CW, SH	**Date:** 7/8/20	

While most restoration sites are recovering well, a few sites continue to need follow-up work. Site CWRD5 needs erosion issues addressed during Phase II of the Rim Drive Project before it can be revegetated. Sites NEERD2 and NEERD2.1 were obliterated pullouts immediately west of the Cleetwood Cove parking lot. However, Park visitors have been parking on these areas and creating additional disturbance due to lack of parking at the Cleetwood Cove parking lot. These sites need barriers to prevent parking impacts prior to implementation of revegetation efforts.

Restoration work has begun at site NEERD3, which is the Cleetwood Cove parking lot. Construction work at the comfort stations and ticket booth sites was not completed until the fall of 2019. Landscaping islands and beds in the parking lot have been revegetated, but these areas are heavily trampled by visitors which presents challenges to restoration. These areas will need to be assessed yearly for traffic patterns and trampling and filled in with plants as problem areas arise. Additional barriers (fencing) may be needed to protect the newly established vegetation. Installation of fencing was not possible in the front of the parking lot due to a buried gas line's unknown location. To protect young vegetation until it is large enough to be visible by parking lot users, plants were placed in groups and circled with large rocks to form a barrier (Figure 15). Each year additional plants will be added, and the rock circles expanded. Once the plants have established, and are more obvious to visitors, then the rock circles will be removed. The back of the parking lot will be worked on during Phase II of the RDRR project. The area presently is not big enough for large recreational vehicles pass through and their back wheels often jump the curb and damage a revegetation site. This area has been sparsely planted in areas that would not be impacted by vehicle traffic (Figure 15). Site NEERD 3.1 is the east embankment of the Cleetwood Cove parking lot and will need to be addressed in future years. It has a steep slope of pumice soil that is continuously eroding and hindering restoration efforts.

Figure 15. Plantings in groups with rock borders to mitigate trampling in heavily trafficked Cleetwood Cove parking lot areas (left). The area at the back of the Cleetwood Cove parking lot will be adjusted to allow for RVs to drive around the comfort station (right). Photos by Carrie Wyler.

Seed Collection

Plant phenology was monitored during the field season through biweekly visits to collection sites, and then later in the season concurrently with seed collection. Phase I no longer requires phenology data to be collected since seed collection is no longer occurring. In 2020, seed collection for Phase II of the project commenced in early August and continued into late-October. The peak seed collection for the bulk of plant species in most of the seed zones occurred from mid-August to late-September (Table 5). Some plant species offered a long collection period due to multiple flowering episodes throughout the growing season. The 2020 season was dry and warm with no snow accumulation until November, allowing for seed collection through the end of October.

Table 5. 2020 seed collection periods for priority collection species indicated by gray shading.

Species	JULY (mid)	July (late)	AUG (early)	AUG (mid)	AUG (late)	SEPT (early)	SEPT (mid)	SEPT (late)	OCT (early)	OCT (mid)	OCT (late)
Eriocoma occidentalis											
Aconogonon davisiae var. *davisiae*											
Calyptridium umbellatum											
Carex pachycarpa											
Drymocallis glandulosa											
Ericameria greenei											
Ericameria nauseosa var. *speciosa*											
Eriogonum marifolium var. *marifolium*											
Holodiscus microphyllus var. *glabrescens*											
Juncus parryi											
Lupinus lepidus var. *lobbii**											
Penstemon species											
Phacelia hastata var. *compacta*											

*Species with two flowering and seed production episodes in one season.

In 2020, Botany staff collected seed from all species on the Phase II RDRR project's species collection list; quantities are listed in Table 6. Grasses and sedges produced abundant seed that was

easy to collect, and thus made up the bulk of the 2020 seed collection. Species that were collected in lower quantities include lupine (*Lupinus* sp.), pussypaws (*Calyptridium umbellatum*), and Greene's goldenbush (*Ericameria greenei*) as predation from unknown insects and mammals significantly reduced the quantity and quality of available seed. However, these species do extremely well at establishing in disturbed areas from seed, and therefore are worth the extra effort to collect. Davis' knotweed (*Aconogonon davisiae* var. *davisiae)* continued to pose a challenge for seed collection and plant propagation efforts by seed. Fertilization appears to be very patchy in the field, and while fruit development can be detected for the first few months after fertilization, many developing seeds appear to be aborted weeks before any viable seed can be acquired. Previous attempts at propagating Davis' knotweed suggest root division/cuttings are viable means of propagation (Trindle and Flessner 2003). During the 2018 field season, several successful trials of propagating fleeceflower from root divisions/cuttings were conducted by the Botany program. The success of these trials establishes this method as a viable option for producing this species for future revegetation needs at CRLA (Figure 16). Salvage of these plants from active construction zones before they are destroyed and propagating them from root divisions will be employed during Phase II revegetation efforts.

Figure 16. Root division cuttings of Davis' knotweed (left); pots of Davis' knotweed emerging from root cuttings (right). Photos by Scott Heisler.

Table 6. Seed collection quantities for 2020.

Seed Zone	Scientific Name	Common Name	Amount collected (grams)
Skell	*Antennaria media*	Alpine pussytoes	0.34
	Boechera horizontalis	Crater Lake rockcress	0.28
	*Eriocoma occidentalis**	Western needlegrass	0
	*Carex pachycarpa**	Many-rib sedge	20.05
	Ceonothus prostratus var. *prostratus*	Mahala mat	4.13
	Diplacus nanus	Dwarf monkeyflower	n/a
	Ericameria nauseosa var. *speciosa**	Showy rabbitbrush	1.41
	Eriogonum ovalifolium var. *nivale*	Cushion buckwheat	0.39

Seed Zone	Scientific Name	Common Name	Amount collected (grams)
	Holodiscus microphyllus var. *glaberscens**	Bush ocean spray	0.61
	Ipomopsis congesta var. *palmifrons*	Palm leaf ballhead gilia	0.28
	*Juncus parryi**	Parry's rush	0
	Linanthus pungens	Granite gilia	n/a
	Lupinus lepidus var. *lobbii**	Prostrate lupine	14.16
	Oxyria digyna	Mountain sorrel	2.92
	Packera cana	Wooly groundsel	1.96
	Penstemon speciosus	Royal penstemon	12.07
	Purshia tridentata	Antelope brush	0.21
Mt. Scott	*Eriocoma occidentalis**	Western needlegrass	80.82
	Aconogonon davisiae var. *davisiae**	Davis' knotweed	87.96
	Alnus alnobetula ssp. *sinuata*	Sitka alder	6.29
	Boechera howellii	Howell's flatseed rockcress	0.81
	Castilleja applegatei var. *applegatei*	Applegate's paintbrush	0.50
	Dieteria canescens var. *shastensis*	Rayless Shasta aster	0.36
	*Ericameria greenei**	Greene's goldenbush	7.02
	Eriogonum marifolium var. *marifolium**	Sierra eriogonum	153.98
	Eriogonum pyrolifolium var. *coryphaeum*	Alpine buckwheat	4.09
	Eucephalus ledophyllus	Cascade aster	0
	Hulsea nana	Dwarf Hulsea	n/a
	*Juncus parryi**	Parry's rush	0
	Lomatium martindalei	Cascade desert parsley	0
	Lupinus albicaulis var. *shastensis*	Pine lupine	17.49
	Lupinus lepidus var. *lobbii**	Prostrate lupine	10.80
	Penstemon davidsonii var. *davidsonii*	Davidson's penstemon	4.44
	Phacelia hastata var. *compacta**	Compact phacelia	5.21
Kerr	*Eriocoma occidentalis**	Western needlegrass	3.47
	Ageratina occidentalis	Western boneset	0.79
	Alnus alnobetula ssp. *sinuata*	Sitka alder	20.10
	Arnica cordifolia	Heart-leaved arnica	10.05
	Arnica longifolia	Longleaf arnica	4.04
	Bromus sitchensis var. *carinatus*	California brome	3.17
	*Carex species**	Sedge species	161.61
	*Drymocallis glandulosa**	Sticky cinquefoil	88.06
	Elymus glaucus ssp. *glaucus*	Blue wildrye	98.62
	*Ericameria greenei**	Green's goldenbush	2.35
	Erigeron glacialis var. *glacialis*	Peregrine fleabane	10.96
	Eriogonum marifolium var. *marifolium**	Sierra eriogonum	7.58
	Eriogonum nudum var. *nudum*	Barestem buckwheat	16.29
	Holodiscus microphyllus var. *glaberscens**	Bush ocean spray	0.33
	*Juncus parryi**	Parry's rush	0
	Lomatium martindalei	Cascade desert parsley	1.15
	Pentsemon rupicola	Cliff penstemon	0.98
	Phacelia hastata var. *compacta**	Compact phacelia	22.02
Dutton	*Eriocoma occidentalis**	Western needlegrass	36.71
	Aconogonon davisiae var. *davisiae**	Davis' knotweed	8.39

Seed Zone	Scientific Name	Common Name	Amount collected (grams)
	Anemone occidentalis	Western pasqueflower	n/a
	Carex pachycarpa	Many-rib sedge	3.40
	Chaenactis alpina	Alpine chaenactis	4.06
	Dieteria canescens var. *shastensis*	Rayless aster	n/a
	*Ericameria greenei**	Greene's goldenbush	3.16
	Eriogonum marifolium var. *marifolium**	Sierra eriogonum	88.82
	Eriogonum nudum var. *nudum*	Barestem buckwheat	3.13
	Eriogonum pyrolifolium var. *coryphaeum*	Alpine buckwheat	4.23
	Eucephalus ledophyllus	Cascade aster	0.30
	*Juncus parryi**	Parry's rush	0
	Lupinus lepidus var. *lobbii**	Prostrate lupine	19.39
	Phacelia hastata var. *compacta**	Compact phacelia	n/a
	Raillardella argentea	Silky raillardella	1.61
Vidae	*Eriocoma occidentalis**	Western needlegrass	55.07
	Aconogonon davisiae var. *davisiae**	Davis' knotweed	10.08
	Anemone occidentalis	Western pasqueflower	407.42
	Arnica viscosa	Shasta arnica	3.40
	Carex halliana	Hall's sedge	8.50
	*Carex pachycarpa**	Many-rib sedge	35.44
	Castilleja species	Paintbrush species	1.06
	Elymus glaucus ssp. *glaucus*	Blue wildrye	36.91
	*Ericameria greenei**	Greene's goldenbush	2.26
	Erigeron glacialis var. *glacialis*	Peregrine fleabane	4.85
	Eriogonum marifolium var. *marifolium**	Sierra eriogonum	77.34
	Eriogonum pyrolifolium var. *coryphaeum*	Alpine buckwheat	2.21
	Erythranthe lewisii	Great purple monkeyflower	0.44
	Holodiscus microphyllus var. *glaberscens* *	Bush ocean spray	0.24
	*Juncus parryi**	Parry's rush	0
	Lupinus albicaulis var. *shastensis*	Pine lupine	32.28
	Lupinus lepidus var. *lobbii**	Prostrate lupine	2.08
	Penstemon davidsonii var. *davidsonii*	Davidson's penstemon	0.90
	Phacelia hastata var. *compacta**	Compact phacelia	14.87
	Senecio triangularis	Arrowleaf groundsel	n/a

*Priority collection species; n/a = seed still being processed.

To augment the amount of plant materials available for revegetation in both Phase I & II of this project, the seed increase services of the Meeker PMC were utilized. The Meeker PMC installed two seed increase fields for California brome (*Bromus sitchensis* var. *carinatus*) and common squirreltail (*Elymus elymoides* ssp. *elymoides*) sown from CRLA seed (Figure 17).

Figure 17. Common squirreltail seed increase field (left) and California brome seed increase field (right) at the Meeker PMC. Photos by Steve Parr.

To maximize seed yield, it was agreed to combine common squirreltail seed from all Phase I RDRR seed zones for seed increase purposes. California brome seeds were combined from the three West Rim Drive seed zones, and from the two East Rim Drive seed zones. Additional California brome and common squirreltail seed from Phase II areas was planted in the seed increase fields in 2018. Production totals are displayed in Table 7. The Meeker PMC experienced a very dry and windy 2020 growing season, which reduced seed production for all species. Seed production will continue into the 2021 season, which will be the final season of seed increase for this project.

Table 7. Production totals from seed increase efforts by the Meeker PMC. CBS = clean bulk seed.

Plant Species and Seed Zone	2017 CBS (lbs.)	2018 CBS (lbs.)	2019 CBS (lbs.)	2020 CBS (lbs.)	Amount CBS (lbs.) Received at CRLA in 2019	Amount CBS (lbs.) Available for Phase II
California brome – West Rim Drive zones	1.6	66.5	157.5	35.0	*0.0*	260.6
California brome – East Rim Drive zones	0.2*	8.4	88.5	26.0	*8.6*	114.5
Squirreltail – all zones	9.6	123.5	218.5	21.0	*20*	352.6

*In 2017, the Meeker PMC's crop of California brome was stunted and produced very little seed (< 1 lb.).

Plant Care and Nursery Work

After the snow melted in 2020, plants that had been overwintered were assessed and inventoried. Plants without any green growth or with rotted roots were discarded. Certain plant species experienced substantially higher survivorship than others, with grasses, sedges and rushes having the greatest success, and species such as Sierra eriogonum, Davidson's penstemon, and Greene's

goldenbush experiencing high mortality. Plants with well-developed roots were transplanted into larger containers while others with detritus, moss, liverwort, or volunteer plants were cleaned (Figure 18). Most of the grass species became infected with a rust in the fall of 2020. The infected areas were trimmed and treated with a baking soda, soap, oil, and water mixture. This helped reduce the rust infestation but not eliminate it. Plants will be assessed in 2021 and if still contaminated will be treated with a chemical fungicide; a Pesticide Use Permitting System proposal has been submitted to facilitate this treatment. Detailed reports of daily nursery activities are on file in the Botany office in the Nursery Activities binder. Over the fall and winter of 2020/2021 1,134 plants are being propagated by CRLA and the DGRC (Table 8). These plants need multiple years of growth in order to become large enough to be planted in heavily disturbed areas.

Figure 18. Overwintered plants emerging from the snow in June 2020 (left). Plant care at the Park's nursery (right). Photos by Carrie Wyler.

Table 8. Plant propagation quantities for Phase II of the RDRR project as of fall 2020.

Zone	Scientific Name	Quantity (# of plants)	Facility	Restoration Site
Skell	*Purshia tridentata*	8	DGRC	Grotto Cove and Skell Head
	Ceanothus prostratus	98	DGRC	For seed increase beds
	Holodiscus microphyllus var. *glabrescens*	60	DGRC	Palisades Pullout
	Penstemon davidsonii var. *davidsonii*	294	CRLA	For seed increase beds
	Ribes viscosissimum	46	CRLA	Grotto Cove and Skell Head islands
Mt. Scott	*Alnus alnobetula* ssp. *sinuata*	20	DGRC	Pumice Castle Overlook
	Penstemon davidsonii var. *davidsonii*	294	CRLA	For seed increase beds
Kerr	*Alnusalnobetula* ssp. *sinuata*	20	DGRC	Pinnacles Junction
	Ribes sp.	98	CRLA	Phantom Ship Overlook islands and Pinnacles Junction
Dutton	*Raillardella argentea*	196	DGRC	For seed increase beds
	TOTAL	1,134		

Site Preparation

All areas that were unable to be restored in 2019 were completed in 2020. Sites that were available for restoration were prepared prior to planting and/or seeding as per established methods.

Planting and Seeding

In 2020, all remaining Phase I restoration sites were completed except for sites that will need to be addressed during Phase II of the project: CWRD5, NWERD2.2, and NEERD3.1. A total of 1,633 plants were planted and 5,463 grams of seed were dispersed across Phase I of the RDRR project area in 2020. Table 9 summarizes the seeding and planting accomplishments by seed zone for the 2020 season.

Table 9. 2020 Summary of restoration planting and seeding accomplishments by seed zone.

Seed Zone	Number of Restored Sites	Total Number Plants Planted	Total Amount Seeds Broadcast (g)
South WRD	2	320	1,361
Central WRD	1	74	582
North WRD	2	184	0
Northwest ERD	2	0	282
Northeast ERD	2	329	0
Rim Village	1	726	3,238
TOTAL	**10**	**1,633**	**5,463**

The east embankment at the Cleetwood Cove parking lot will continue to need slope stabilization and erosion control for revegetation efforts to be successful. This embankment was disturbed by contractors stacking cut logs on it when they were clearing trees to expand the parking lot. The embankment is steep and consists of loose pumice soil, which collapses when walked on. The site does not hold seed or water well, and it has been difficult to restore and revegetate. In 2019 large logs and rocks were put into place and areas were vertically mulched with little success. This area needs to be reassessed in 2021 to develop a new plan of action. Creating and burying waddles stuffed with native seed and planting behind them is a method to be considered in 2021. Every revegetation attempt creates more soil disturbance and erosion, so this need to be considered. Hall's sedge (*Carex halliana*) is presently being propagated for this area; its fibrous and extensive roots system may aid in soil stabilization.

Site Documentation and Monitoring

Yearly site documentation and monitoring is completed for all sites that were restored. For these sites, one- two- and three-year post-restoration photo points were taken, and monitoring forms were completed as a means of assessing the success of revegetation efforts and determining additional site needs (Figure 19). Due to the Covid-19 pandemic, there was insufficient staff to conduct formal monitoring. An informal assessment directed the 2020 outplanting and seeding work.

Figure 19. Site NEERD0.1 in 2016 (left) and in 2019 (right). Photos by Carrie Wyler.

In past years overview documents were created for each restoration site, including a map of the site, description of the site location, and location of photo points These documents show the precise area and location of each site and can be used in combination with monitoring forms as a way of tracking restoration progress from year to year at specific sites. Binders for each zone were created/updated and contain site maps and monitoring documentation for each restoration site. These binders are on file in the Botany office and available for reference by future staff. Overview maps, photos, and complete site documentation forms for all sites can be found on the Botany server.

Monitoring results showed a clear pattern: restored sites that were protected from further impacts (e.g., vehicle damage, trampling) did markedly better than those that experienced additional and/or ongoing impacts. Forty-eight of the 62 restored sites are doing well, and vegetative recovery is progressing with no further action needed. The other 14 sites were either damaged by vehicle traffic, trampled by Park visitors, or have challenging site conditions (e.g., steep slopes, erosion, unstable soils) that make revegetation difficult. Supplemental planting and seeding in the future will continue to assist the recovery of restoration sites that are struggling, and some sites may need fencing and/or signage to protect them from further damage especially at the Watchman Overlook and Cleetwood Cove parking lot.

Monitoring data also captured the early colonization of most restoration sites that were revegetated during 2016-2019 in the Phase I RDRR project area by the native plants spreading groundsmoke (*Gayophytum diffusum*) and pussypaws (*Calyptridium umbellatum*). These species were not recorded during the drafting of restoration prescriptions and are serving the role of pioneering species (Figure 20). Prostrate lupine (*Lupinus lepidus* var. *lobbii*) is a species that was captured in the pre-disturbance site documentation, but it did not do well in plant propagation attempts and was not abundant in initial site monitoring. However, in 2020 it was obvious that this species has done extremely well in establishing itself in disturbed areas from seed. Due to these observations, seed from these species will be collected for Phase II revegetation efforts for broadcast seed mixes.

Figure 20. Spreading groundsmoke (left) and pussypaws (right). Photos by Melody Frederic.

Special Status Plant Management

During the 2020 season, Phase II of the RDRR project was surveyed for special status plant species. Eleven rare plant populations were encountered in the project area that will need protections (e.g., installing orange fencing around a population buffer) during construction. Some of these rare plant populations will experience unavoidable impacts (Figure 21) due to their occurrence in deep patch and edge stabilization treatment areas, in the road shoulder, in cracks between rock walls and pavement, or otherwise in the path of impact. In these cases, rare plants will be salvaged ahead of construction and held over at the Ball Diamond nursery until they can be replanted. Spatial and population data are housed on the Park's Botany server.

A five-needle pine survey was also conducted in 2020 and in total, 2480 datum points were collected, many potentially representing multiple trees in the case of shared base areas. An overview of the collected data is presented in Figure 22.

Figure 21. Some rare plants will experience unavoidable road construction impacts: shaggy hawkweed (left) and Shasta arnica (right). Photos by Jen Hooke

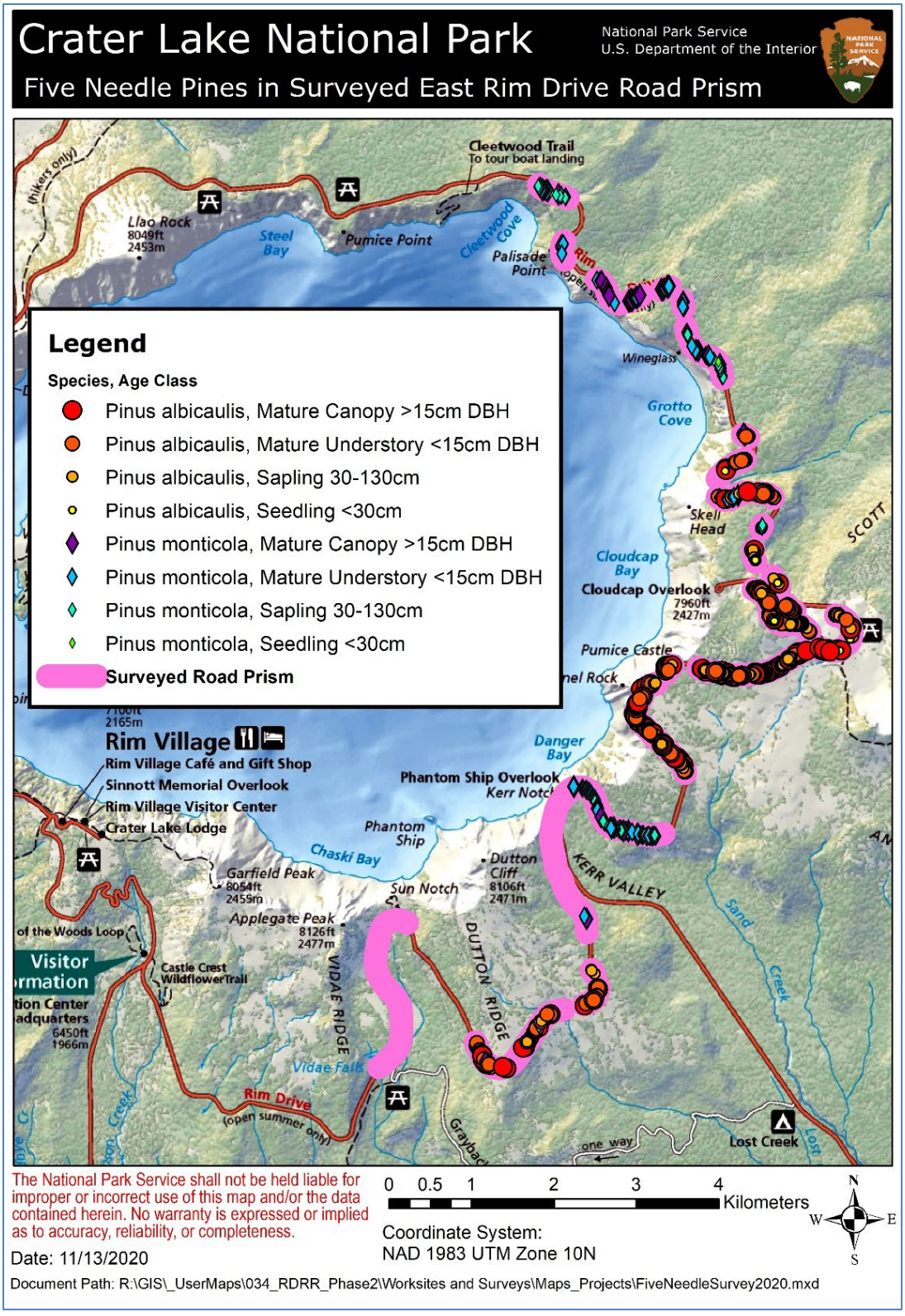

Figure 22. Map of surveyed whitebark pine (*P. albicaulis)* and western white pine (*P. monticola)* in the proposed disturbance areas for Phase II of the RDRR project. Map by Scott Heisler.

Invasive Vegetation Management

A total of 42,156 invasive plants were removed from project areas during the 2020 season. Invasive plants were encountered most frequently at Rim Village. Invasive plant abundances are compared from 2017 to 2020 in Table 10. Maps of invasive plant locations for 2020 are broken up into three zones: East Rim Drive, Pole Bridge Creek Quarry, and Rim Village, and displayed in Figures 23 and 24, respectively. No invasive plants were found on West Rim Drive during the 2020 field season, although it was not surveyed in its entirety due to workload limitations.

Table 10. Invasive plant abundance (number of plants) within the RDRR project area from 2017--2020.

Region	Invasive Plant Species	2017 Abundance	2018 Abundance	2019 Abundance	2020 Abundance
Pole Bridge Creek Quarry	Bitter winter cress (*Barbarea vulgaris*)	10	9	95	4
	Red sand-spurrey (*Spergularia rubra*)	12	0	0	0
	Common dandelion (*Taraxacum officinale*)	9	0	0	13
	St. John's wort (*Hypericum perforatum)*	0	0	0	8
	Erect cinquefoil (*Potentilla recta*)	0	0	0	20
East Rim Drive	Bitter winter cress (*Barbarea vulgaris*)	56	2	0	0
	Canola (*Brassica napus*)	0	2	0	2
	Smooth brome (*Bromus inermis*)	5,157	130	0	500
	Cheatgrass (*Bromus tectorum*)	1	0	0	0
	St. John's wort (*Hypericum perforatum*)	25	0	0	6
	Annual bluegrass (*Poa annua*)	40	0	0	0
	Canada bluegrass (*Poa compressa)*	0	0	200	0
	Kentucky bluegrass *(Poa pratensis)*	0	0	0	38
	Common knotweed (*Polygonum aviculare* ssp. *depressum*)	57	0	0	0
	Sheep sorrel (*Rumex acetosella)*	0	0	80	0
	Stinking willie (*Senecio jacobaea*)	67	0	0	0
	Red sand-spurrey (*Spergularia rubra*)	1	0	0	0
	Common dandelion (*Taraxacum officinale*)	368	36	585	277
West Rim Drive	Sheep sorrel (*Rumex acetosella)*	0	0	12	0
	Timothy (*Phleum pratense*)	0	1	0	0
Rim Village	Bitter winter cress (*Barbarea vulgaris*)	640	98	294	178
	Common mouse-ear chickweed (*Cerastium fontanum* ssp. *vulgare*)	0	1	0	0
	Bull thistle (*Cirsium vulgare*)	1	0	0	0
	Orchard grass (*Dactylis glomerata*)	2	0	0	0
	Common St. John's wort (*Hypericum perforatum*)	4	0	0	0
	Field cress (*Lepidium campestre)*	0	0	1	0
	Common bird's-foot trefoil (*Lotus corniculatus*)	1	0	0	0
	Pineapple weed (*Matricaria discoidea*)	725	719	550	7

Region	Invasive Plant Species	2017 Abundance	2018 Abundance	2019 Abundance	2020 Abundance
	Yellow sweet clover (*Mellilotus officinalis*)	0	0	0	10
	Buckhorn plantain (*Plantago lanceolata*)	3	1	3	2
	Common plantain (*Plantago major*)	17	0	3	0
	Annual bluegrass (*Poa annua*)	40	0	0	75
	Common knotweed (*Polygonum aviculare* ssp. *depressum)*	762	305	3,930	1,730
	Sheep sorrel (*Rumex acetosella)*	25,998	7,267	1,719	2,942
	Red sand-spurrey (*Spergularia rubra*)	16,490	6,142	69,174	28,050
	Common dandelion (*Taraxacum officinale*)	260	73	69	27
	Dutch clover (*Trifolium repens*)	535	102	128	15
	Total	51,281	14,888	76,840	42,156

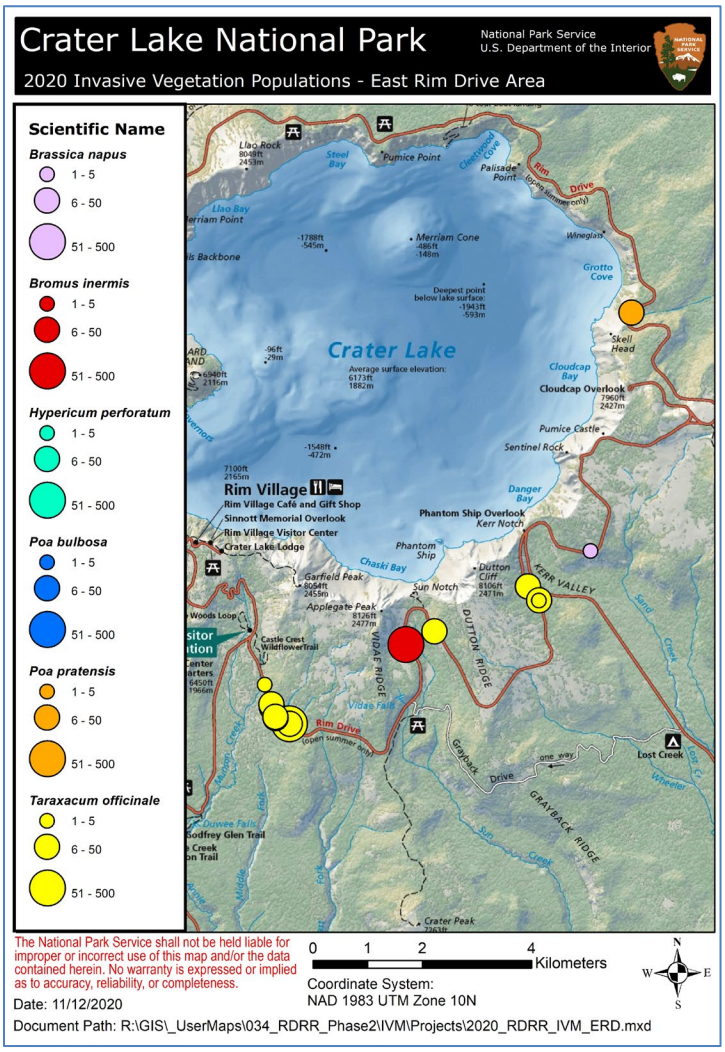

Figure 23. Map of invasive populations treated in the RDRR project area on East Rim Drive. Map by Scott Heisler.

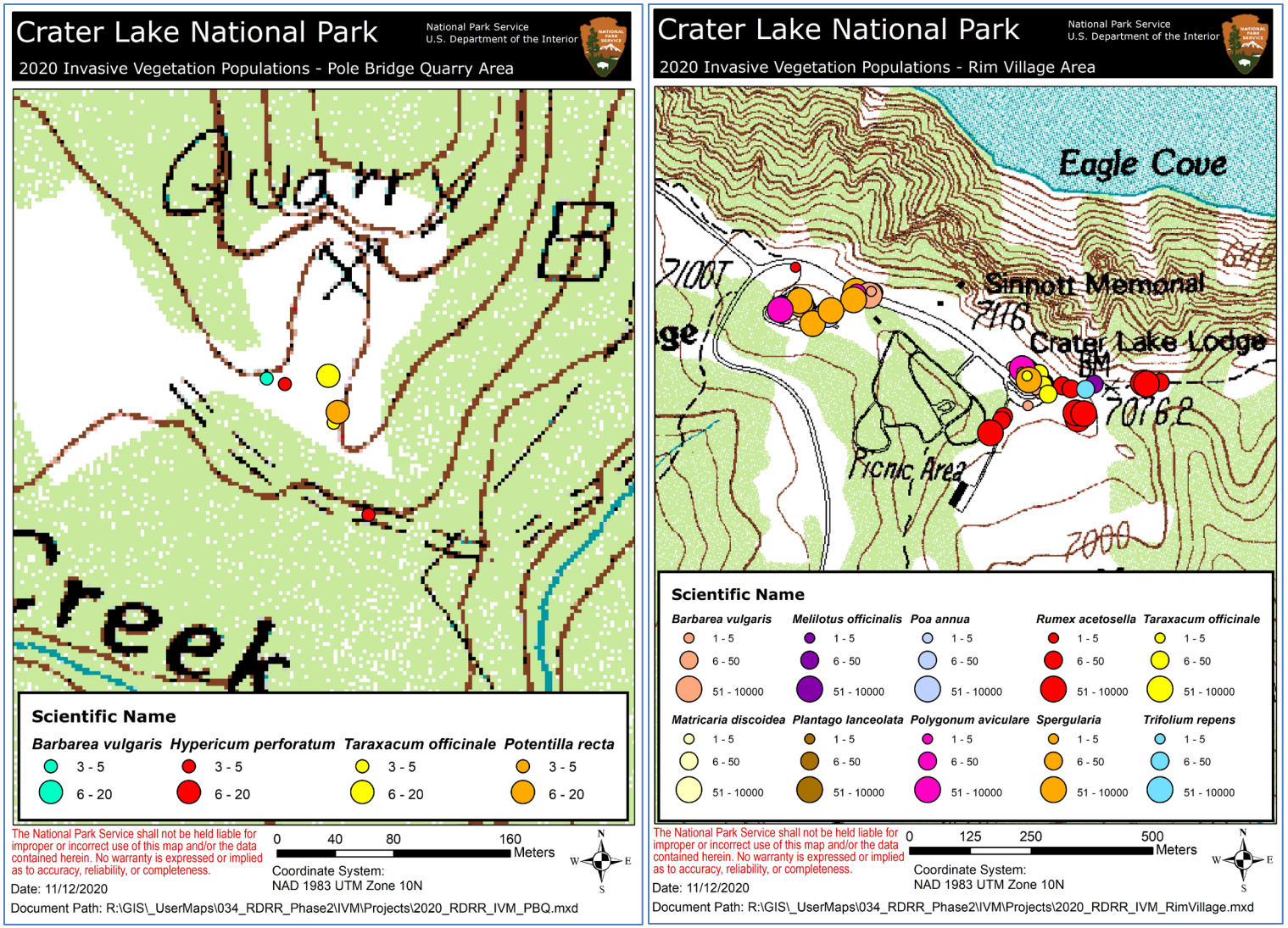

Figure 24. Map of invasive plant populations treated at the Pole Bridge Creek Quarry staging area (left). Map of invasive populations for the RDRR project area at Rim Village (right). Maps by Scott Heisler.

Buckhorn plantain (*Plantago lanceolata*), pineapple weed (*Matricaria discoidea*), and common St. John's wort (*Hypericum perforatum*) populations were treated in their entirety with all observed individuals removed. However, large invasive plant populations of bitter winter cress (*Barbarea vulgaris*), sheep sorrel (*Rumex acetosella*), and red sand-spurrey (*Spergularia rubra*) at Rim Village were treated as time allowed. The large population of sheep sorrel by the Crater Lake Lodge has been subject to a large control effort annually since 2013, often using volunteer groups. This site was first treated with herbicide in the fall of 2017 and was treated again in June-July 2018, 2019, and 2020. Sheep sorrel abundance was greatly reduced in 2018 and 2019, which may be attributable to the effectiveness of chemical treatment. In 2020 two new population areas were discovered which led to an increase in numbers from 2019. Common knotweed (*Polygonum aviculare* ssp. *depressum*) was another species that continues to increase greatly in number for unknown reasons, especially around the Lodge. This is another difficult species to treat by manual means due to its deep root systems. Red sand-spurrey (*Spergularia rubra*) has become an increasingly abundant invasive plant species, forming mats in some disturbed areas and outcompeting native plants. In 2019, Botany staff manually removed red sand-spurrey from the landscape islands around the Rim Village Café and Gifts building and chemically treated it in 2020. This treatment was followed up in the fall of 2020 by planting 2,642 native plants and dispersing and raking in 3,238 g of native seed (gathered from Rim Village) in hopes of outcompeting any new invasive plant species (Figure 25). These areas will need to be monitored in the future and treated with herbicide before flowering in early spring, and again in late summer to control the plant during its multiple flowering periods.

Figure 25. Potted plants laid out for planting in treated areas at Rim Village (left). The Botany crew planting in red sand-spurrey treatment areas behind the Rim Café (right). Photos by Carrie Wyler.

Discussion

During the 2020 season all unfished revegetation sites not needing additional Phase II contractor assistance were completed for Phase I. During 2021, wrap-up efforts for Phase I should focus on areas that need additional assistance with recovery such as highly visited and trampled areas. During 2019 and 2020 large rock rings were made around grouped plantings at the Cleetwood Cove parking lot, Glacial Scratches pullout areas, and Watchman Overlook. This technique has been found to be successful in deterring trampling if larger rocks are used and will be used in future restoration areas. Some areas may need more obvious exclusion methods such as fencing and signage. Monitoring and completing site documentation for areas that underwent restoration work during the 2015—2019 field seasons will aid in evaluating the success of these efforts and needs to be completed in 2021. This was not completed in 2020 due to the lack of time and staffing resulting from the Covid-19 pandemic. These evaluations are vital for tracking efficacy of restoration efforts, identifying areas in need of additional plant materials, and for informing managers in the planning of future restoration efforts.

Recommendations and needs for RDRR work in the 2021 field season include:

All plants that overwintered in 2020/2021 need to be assessed for status and health. Root-bound plants will need to be transplanted into larger containers or divided as soon as practical after the snow melts. Plants will need fertilization to assist with survival and growth. The plants selected for overwintering were chosen because of their quick root development and overall hardiness. If plants aren't transplanted, many will die due to being extremely root-bound. Care should be taken to not expose newly transplanted plants to water, light, or temperature shock. All containerized plants should be checked for moss or liverwort growth and it should be removed if present to prevent disease. All remaining Phase I plants should be outplanted in 2021 at sites that are still sparsely vegetated or moved to other projects in the same zones.

Surveys in areas with previously documented invasive plant populations should be conducted several times during the growing season, with priority given to areas near rare plant populations (e.g., Diamond Lake overlook, the Watchman Overlook, Grotto Cove, and Skell Head). The entire project area needs to be thoroughly surveyed (e.g., walked) for invasive plants at least twice throughout the 2021 field season.

The National Weather Service has an extremely useful weather database with daily, monthly, and yearly data summaries (http://w2.weather.gov/climate/xmacis.php?wfo=mfr) that should be used to help inform when to water newly planted seedlings and provides information for seed collection. It also facilitates year-to-year comparisons by providing data on annual snow loads and precipitation amounts.

Restoration prescriptions will need to be developed for Roundtop Quarry. Its slopes were mechanically recontoured by the Phase I contractors leaving the disturbed areas completely devoid of vegetation. Once the Park has determined the desired footprint for future use of this area, disturbed areas outside this footprint need to be revegetated and restored. Some of the seed being produced at

the Meeker PMC can be used at this site. Seed will need to be raked in with Park compost and native debris distributed. The area will need to be mapped, documented, and monitored in Phase II for restoration progress and surveyed diligently for invasive plant species.

The Cleetwood Cove parking lot will continue to need revegetation work in 2021, after accessing restoration success from 2020 efforts.

In past years overview monitoring documents were created for each restoration site, including a map of the site, description of the site location, and location of photo points. Workload limits stemming from the Covid-19 pandemic did not allow time to complete these this year; they will need finished in 2021.

Forty pinemat manzanita (*Arctostaphylos nevadensis*) plants in one-gallon pots were planted in the Cleetwood Cove parking lot landscaping islands during the fall of 2019 in groups of three with a rock border. These were placed in larger pots to increase their size with the hope that trampling impacts would be lessened if vegetation cover was greater and the rock border would create a visual cue for visitors to not trample them. Pinemat manzanita plants that originated from their original (smaller than one-gallon containers) were planted in the landscaping islands in 2017 and were almost all killed from trampling impacts as of fall 2018. These larger plants seemed to have a higher survival rate than the smaller ones. In 2020, 47 pinemat manzanita plants from one-gallon pots were outplanted in the area. An assessment should be done to determine if this technique was successful, and if so, it would be good to use larger, older plants with rock borders in heavily trafficked areas of the project in the future.

Skell Head Overlook (NEERD16) will also need to be reassessed in 2021. After monitoring the site in 2019 it was discovered that only 5 plants out of 126 planted and 711 g of dispersed seed survived the 2019 season. The lack of success at this restoration site may be due to the exposed nature of the site, the high wind exposure, and the fact that the contractors did not apply topsoil to this site, only gravelly subsoil contaminated with asphalt chunks. To ameliorate the harsh conditions at this site, 418 g of seed was raked in, then six truck beds of Park-sourced compost were piled on top of the seed mix. A truck bed of windblown native pumice soil salvaged from paved pullouts on East Rim Drive was then dispersed on top of the compost in hopes of holding everything in place. However, five days later a storm came through the area and dispersed much of the recently applied material off-site. Much of the material was captured by the rock walls on site and was gathered and re-dispersed onto the site right before a heavy snowstorm hit the area. In the spring of 2020, it was found that the material had once again been blown from the site. This site will be addressed in Phase II of the RDRR project and have the gravelly subsoil removed and new topsoil added. Some type of barrier cloth may be needed to keep the soil in place until plants are established.

Literature Cited

Beck, J.S., A.H. Fraser, C.S. Wyler, M.C. Frederic, and K.M Williams. 2017. Rim Drive Rehabilitation Revegetation Project 2016 Annual Report. Crater Lake National Park, Crater Lake, Oregon.

Department of the Interior National Park Service. 2017. Crater Lake National Park Invasive Vegetation Management Plan Environmental Assessment. Crater Lake, Oregon.

Gregory, R., K. Stella, and J. Beck. 2015. Crater Lake National Park Revegetation Plan for Rim Drive Rehabilitation and Rockfall Mitigation Projects. Unpublished report on file at Crater Lake National Park headquarters.

Heisler, S.E., C.S. Wyler, J.S. Hooke, T.L. Chizinski, M.C. Frederic, and K.M. Scott. 2019. Pacific Crest Well Pipeline Revegetation Project 2018 Annual Report. National Park Service, Crater Lake National Park, Crater Lake, Oregon.

Seed Collection Guideline for National Parks. Taliga C.E., USDA NRCS, Brown J.H., NPS DSC T, Denver Colorado. November 2015.

Trindle, J.D. and T.R. Flessner. 2003. Propagation protocol for vegetative production of container *Polygonum davisiae* Brewer ex Gray plants (1-yr crowns in 6); USDA NRCS – Corvallis Plant Materials Center, Corvallis, Oregon. In: Native Plant Network. URL: https://npn.rngr.net/npn/propagation/protocols/polygonaceae-polygonum-2475/?searchterm=polygonum%20davisiae [accessed 25 March 2020]

Appendix A:

CRLA RDRR Project Phase II: Master Revegetation List from 70% Plan Set (9/01/20)

ID#	Station	Lake/NonLake	Page(s)	Type	Seed Zone	Location
1	27+ to 28+	Lake	D.3	Pullout to obliterate	Skell	Just past Cleetwood Cove
2	82+ to 85+	Lake	D.7	Shrink pullout	Skell	Palisades Overlook
3	101+ to 105+	Lake	D.8/ F.4	Shrink pullout	Skell	Palisades Point
4	189+ to 192+	Lake	D.14/ F.6	Shrink pullout; figure out what to do with trampled area	Skell	Upper Grotto Cove
5	225+ to 229+	Lake	D.17/F.7	Skell Head Overlook: replace soil in overlook landscaping beds	Skell	Skell Head
6	243+ to 249+	NonLake	D.18	Reestablish BOEHOR – Deep Patch	Skell	Bear Creek (just east of Skell Head)
7	340+ to 342+	NonLake	D.25/ F.9	Restoration of trampled areas	Mt. Scott	Whitebark Pine Picnic Area
8	349+ to 350+	NonLake	D.25/ F.10	Trailhead landscaping	Mt. Scott	Mt. Scott Trailhead
9	24+ to 25+	CC North	F.28	Shrink pullout	Mt. Scott	Mt. Scott Cirque Overlook
10	376+ to 378+	NonLake	D.27	Pullout to obliterate	Mt. Scott	On back side of Cloudcap
11	421+ to 423+	Lake	D.30/ F.11	Landscaping island	Mt. Scott	Pumice Castle Overlook
12	464+ to 465+	NonLake	D.33	Pullout to obliterate	Mt. Scott	South of Reflection Point
13	497+ to 498+	NonLake	D.35-36	Pullout to mostly obliterate (1 car)	Kerr	Just north of Anderson Bluffs
14	~550	Lake	D.39/F.14	Landscaping islands	Kerr	Kerr Notch
15	553+ to 557+	NonLake	D.39-40	Shrink roadway	Kerr	Junction with Pinnacles Road at Kerr Notch
16	604+ to 606+	NonLake	D.43	Pullout to obliterate	Kerr	Just south of Dutton Cliffs
17	644+ to 646+	NonLake	D.46	Pullout to obliterate	Dutton	DU01, Dutton Ridge
18	686+ to 688+	NonLake	D.48-49/ F.18	Shrink pullout	Dutton	Klamath Marsh Overlook
19	759+ to 763+	Lake	D.54/ F.23	Shrink parking lot; culvert replacement	Vidae	Sun Notch Trailhead
20	831+ to 836+	NonLake	D.58	Improve intersection	Vidae	Vidae Falls
21	966+ to 967+	Lake	D.68	Pullout to obliterate	Vidae	Near CCWG

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

April 2021

National Park Service
U.S. Department of the Interior

Crater Lake National Park
P.O. Box 7
Crater Lake, Oregon 97604