JEFFERSON
COUNTY COLORADO
Open Space

The Jefferson County Open Space Resiliency Framework

Preserve. Protect. Provide.

2019

ACKNOWLEDGEMENTS

Lead Authors & Development Team

Victoria Arling, Masters of the Environment Graduate Program, University of Colorado
Emily Gear, Masters of the Environment Graduate Program, University of Colorado
Madeleine Green, Masters of the Environment Graduate Program, University of Colorado
Kate Oetheimer, Masters of the Environment Graduate Program, University of Colorado
Katrina Pickering, Masters of the Environment Graduate Program, University of Colorado
Christine Zenel, Masters of the Environment Graduate Program, University of Colorado

Advisory Team

Scot Grossman, Projects Supervisor, JCOS
Paul Lander, Faculty Advisor, University of Colorado
Andrew Rayburn, Natural Resources Team Supervisor, JCOS
Nancy York, Planning Supervisor, JCOS

JCOS Contributors & Reviewers

Administration & Real Estate Team
Gina Barton, Manager
Christine Strickland, Real Estate Assistant

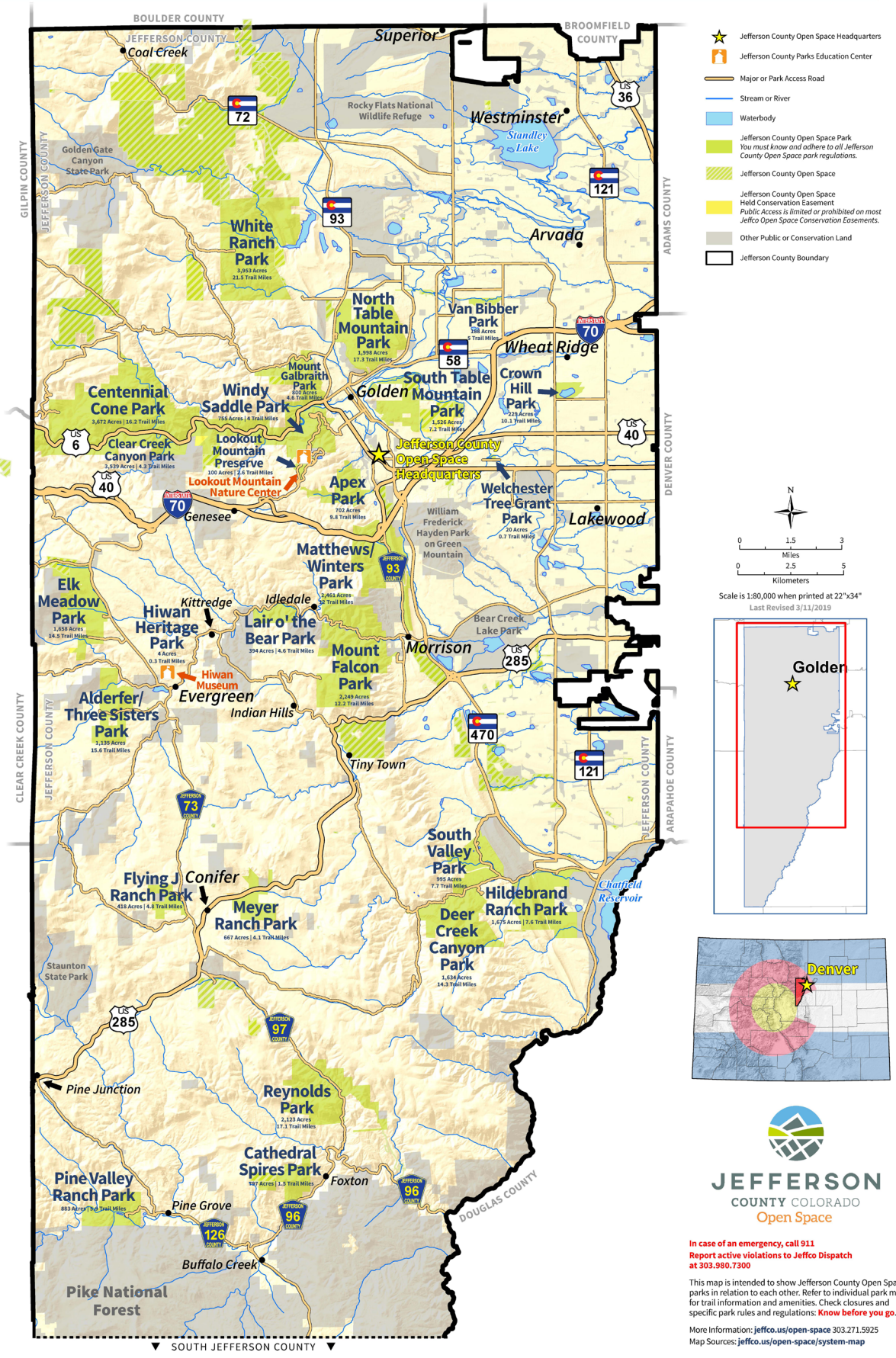
Community Connections Team
Matt Robbins, Manager
Lilly Bock-Brownstein, Communications Specialist
Shaina Young, Community Specialist

Planning & Projects Team
Andy Scanlan, Manager
Guthrie Alexander, Senior Project Manager
Kristina Duff, Senior Planner
Elizabeth O'Brien, Planner
Rob Thayer, GIS Analyst Lead
Chris White, GIS Analyst

Stewardship Team
Mike Foster, Manager
Alicia Doran, Invasive Species Management Coordinator
Jerry Bader, Natural Resources Lead
Irene Weber, Natural Resources Senior Specialist
Josh Garcia, Trails Program Coordinator
Scott Waters, Trails Senior Specialist

Visitor Services Team
Mary Ann Bonnell, Manager
Alexis Sohlden, Visitor Information Coordinator
Ben Stanley, Park Ranger Lead

JEFFERSON COUNTY OPEN SPACE
Park System



JEFFERSON COUNTY COLORADO
Open Space

In case of an emergency, call 911
Report active violations to Jeffco Dispatch at 303.980.7300

This map is intended to show Jefferson County Open Space parks in relation to each other. Refer to individual park maps for trail information and amenities. Check closures and specific park rules and regulations: **Know before you go.**

More Information: **jeffco.us/open-space** 303.271.5925
Map Sources: **jeffco.us/open-space/system-map**

EXECUTIVE SUMMARY

To meet the mission of Jefferson County Open Space (JCOS) - preserve open space and parkland, protect park and natural resources, and provide healthy, nature-based experiences - this Framework establishes land management guidelines which account for changing conditions in the JCOS park system. The Framework incorporates existing and predicted shocks and stressors for three main spheres of resilience (social, ecological, and built infrastructure) and was developed to aid the organization in continuing to manage its resources despite these challenges. This Framework is not a management prescription, but rather frames a different way of thinking to help JCOS further develop the capacity of its organization to cope with unexpected changes and significant shocks and stressors. This document illustrates a vision of resiliency for the organization, evaluates existing conditions within the park system, and provides a proactive, decision making tool to prioritize projects and management strategies based on a resilience score.

What is Resiliency?

The Jefferson County Open Space Resiliency Framework (the Framework) draws inspiration from the definition of resilience established by the Colorado Resiliency Office while establishing its own interpretation of resiliency as it relates to the social, ecological, and built infrastructure elements of the park system. For JCOS, resilience is:

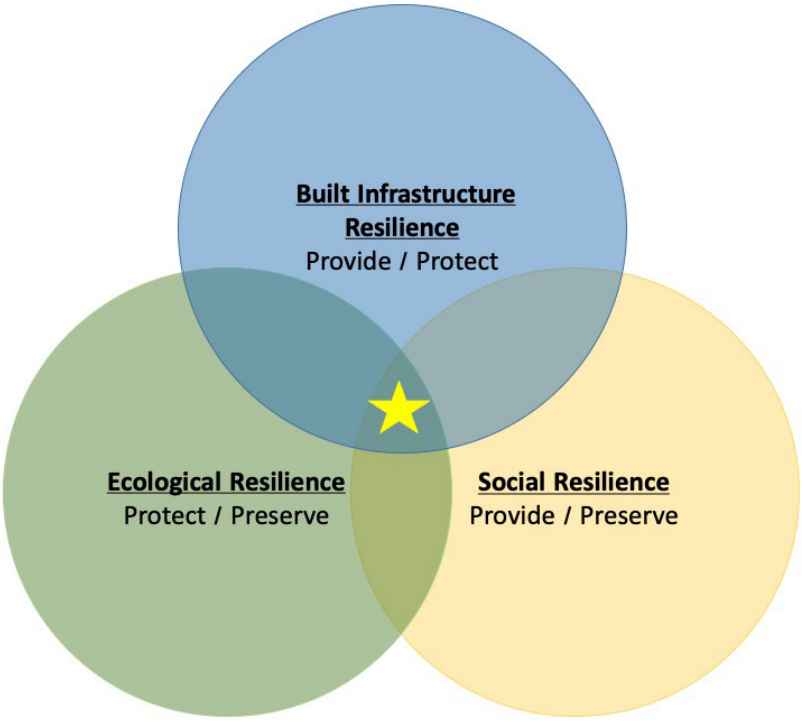
The ability of Jefferson County Open Space to rebound, positively adapt to, or thrive amidst changing conditions or challenges – including social, environmental, and biological shocks or stressors.

Planning for resiliency enables proactive, holistic management because it focuses on strategizing ways to build the capacity of the park system to cope with uncertainty and perpetually changing conditions. Resiliency planning acknowledges that the park system is dynamic, rather than static, and strives to work in tandem with this essential characteristic. By strengthening features that increase resilience in the park system, JCOS will further equip its organization and the resources it manages to positively rebound from, adapt to, and thrive amidst current and future change – all while maintaining desired functions.

Three Spheres of Resilience

The Framework is centered around three spheres of resilience: social, ecological, and built infrastructure resilience. While these spheres support unique goals, they also intersect. Plans, projects, and management strategies focused only on one or two spheres risk ignoring other important dimensions of the organization. Ultimately, the *Preserve, Protect*, and *Provide* mission of JCOS is best accomplished at the intersection of social, ecological, and built infrastructure resilience.

- **Social resilience** is characterized by the provision of relevant nature-based experiences and the positive interactions of visitors with each other, the organization, and the natural and cultural environment of JCOS parks.
- **Ecological resilience** is characterized by the protection of species and habitats found within the JCOS park system.
- **Built infrastructure resilience** is characterized by the construction and maintenance of functioning, safe, and logically positioned features within the JCOS park system such as parking lots, restrooms, gathering spaces, and trails.



The Jefferson County Open Space Resiliency Scorecard (the Scorecard) encourages consideration of how plans, projects, and management strategies associated with one sphere may impact the plans, projects, and management strategies of the others. This Scorecard is presented in Section 5 of the Framework.

Understanding Shocks and Stressors

The overarching goal of this Framework is to chart a path toward a resilient future in which JCOS's vulnerability to adverse changes and potential disasters is reduced, and the ability to rebound from and positively adapt to shocks and stressors is enhanced. Shocks and stressors are not necessarily negative; they are merely disruptions to the system that require adaptations and proactive mitigation. Section 2 presents shocks and stressors in JCOS and how they can further increase the vulnerability of the park system to changing conditions.

Shocks are direct disturbances that disrupt the functions of a given system. Shocks include but are not limited to wildfire, flooding, extreme weather events, or economic change.

Stressors are indirect disturbances. They are underlying, long-term and recurring events that disrupt the functions of a given system and undermine the ability of that system to recover from or adapt to a shock. Stressors include but are not limited to drought, invasive species, changing recreation trends, and demographic shifts.

Shocks and stressors within the JCOS park system vary in their intensity and frequency. Most shocks are high intensity but low frequency events, while stressors are more variable. The shocks and stressors in the JCOS park system can also be categorized as social, environmental, or biological.

Social shocks and stressors relate to human behavior, **environmental** shocks and stressors relate to abiotic (non-living) factors, and **biological** shocks and stressors relate to biotic (living) factors.

By incorporating resiliency into plans, projects, and management strategies, JCOS will be able to reduce its vulnerability and enhance its ability to adapt to shocks and stressors.

Features of Resiliency

The Framework is grounded in three core features that make a resilient system: diversity, connectivity, and redundancy. These features are defined as:

- **Diversity:** multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressors.
- **Connectivity:** physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the entire current and future JCOS park system.
- **Redundancy:** fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.

By focusing on and managing for these features, the JCOS park system will be better able to rebound from, positively adapt to, or thrive amidst shocks and stressors.

The Scorecard

The Scorecard, presented in Section 5 of the Framework, is intended to serve as a decision making tool to complement existing ways JCOS teams are currently comparing, evaluating, and prioritizing projects. The Scorecard is meant to capitalize on the knowledge and expertise of JCOS staff. It allows for cross-comparison of projects based on their ability to increase resiliency in the park system through diversity, connectivity, and redundancy in the three spheres of resilience. While the Scorecard is not meant to be the final decision making point on any project or strategy, it is meant to encourage JCOS staff to integrate resilience concepts and thinking into decision making processes.

The core of the Scorecard lies in the resilience score, a score calculated from a unique set of criteria tied to a resilience feature. The quantitative value, based on a qualitative justification, indicates how well a project is expected to build out the identified resilience features. After evaluating a project's resilience score, the evaluator must additionally consider how the project will help JCOS adapt to relevant shocks and stressors. This supplementary section provides an opportunity for JCOS staff to understand how a project will ultimately increase resiliency within the JCOS park system.

Together, the Framework and Scorecard will help develop the capacity of the JCOS park system to rebound from, positively adapt to, or thrive amidst changing conditions or challenges.

Table of Contents

Section 1
Introduction & Purpose

1. INTRODUCTION & PURPOSE

The mission of Jefferson County Open Space (JCOS) is to preserve open space and parkland, protect park and natural resources, and provide healthy, nature-based experiences. JCOS serves an estimated seven million visitors annually on more than 56,000 acres of land. Uniquely located at the intersection of the Great Plains and the foothills of the Rocky Mountains, JCOS parks offer world class recreation opportunities on a range of landscapes from short grass prairie and subalpine forests, to red rock geologic formations and steep canyon walls above riparian ecosystems. Since 1972, the organization has been able to provide these experiences to millions of Coloradans and visitors and conserve ecologically and culturally significant lands, thanks to a one half of one percent sales tax voted into place in Jefferson County. This sales tax enables the JCOS park system to operate without visitor fees, creating a significant backyard amenity to those living in the Denver Metro Area and an accessible outdoor tourism opportunity for visitors. The surrounding Denver Metro Area currently experiences population growth at two percent per year, posing a challenge for the organization to continue creating transformative programs, ensuring safety within their parks, and balancing visitor use with the preservation of natural and cultural resources.[1] JCOS is also a mature park system and parts of the built infrastructure are aging. Furthermore, the JCOS park system is not immune to current ecological threats, including climate change and extreme weather events such as wildfire and drought.

The *Jefferson County Open Space Resiliency Framework*, hereafter referred to as the Framework, was developed to aid the organization in continuing to manage its resources despite these challenges. The Framework is intended to help the organization prioritize projects and management strategies to increase social, ecological, and built infrastructure resilience within the JCOS park system. This Framework is not a management prescription, but rather frames a different way of thinking that will help JCOS further develop the capacity of its organization to cope with unexpected change and significant shocks and stressors. The Framework illustrates a vision of resiliency for the organization, evaluates existing conditions within the park system, and provides a proactive, decision making tool to prioritize projects and management strategies based on a resilience score.

1.1 Framework Objectives

This Framework is designed to serve as an adaptive guiding document for JCOS staff to prioritize projects and management strategies according to how well they promote social, ecological, and built infrastructure resilience (detailed in Sec. 1.3). The Framework was developed by a group of graduate students at the University of Colorado, Masters of the Environment (MENV) program in conjunction with JCOS staff. The Framework is intended to:

- ◊ Illustrate the benefits of integrating resilience theory into JCOS projects and management strategies.
- ◊ Establish a JCOS vision of resiliency that encompasses the social, ecological, and built infrastructure elements of the park system.
- ◊ Identify and evaluate current and potential shocks and stressors within the JCOS park system.
- ◊ Provide guidelines on how to use the Jefferson County Open Space Resiliency Scorecard (the Scorecard) - a tool that will support the prioritization of projects and management strategies according to how well they improve resiliency in the park system.

As illustrated by the JCOS *Vision to Action* model (Fig. 1), the Framework is a JCOS System-Wide Plan that is

Figure 1: The JCOS Vision to Action model that illustrates the planning cascade utilized by the organization. The Framework is a JCOS System-Wide Plan, informed by the JCOS Vision, Mission, and the Conservation Greenprint. The Framework falls within the "system-wide plans" level of this model.

complementary to, and informed by, the JCOS Vision, Mission, and *Conservation Greenprint* (5-year Strategic Plan). In turn, the Framework informs other system-wide plans, Park Plans, Action Plans, and finer-scale projects and planning efforts.

1.2 What is Resiliency?

Resiliency planning is a growing trend on local, state, and national levels. In 2015, the Colorado Governor's Office, along with the Colorado Resiliency Office (CRO) under the Colorado Department of Local Affairs (DOLA), created and adopted the Colorado Resiliency Framework (CRF). The CRF was developed in response to the severe floods and wildfires Colorado experienced in 2012 and 2013. The document lays out guidelines and strategies for municipalities statewide to approach community planning with an understanding that uncertainty, including climate change and natural disasters, are part of our future. Since the CRF was adopted, many municipalities, state government branches, and multi-actor partnerships have created resiliency projects or plans, including but not limited to, the I-70 Risk and Resilience Pilot, Resilient St. Vrain, the Larimer Community Resilience Framework, the El Paso County Resiliency Plan, and the City of Boulder Resilience Strategy. Although other public land management agencies such as the National Park Service integrate resilience principles into planning efforts, this Framework is unique because it sets out an entire plan dedicated to open space-specific resiliency.

While the CRF establishes support for public entities across Colorado to implement resiliency projects and plans at the local level, it does not specifically establish a structure of support for open space or other land management agencies. Therefore, the Framework draws inspiration from the CRF, while establishing its own interpretation of resiliency as it relates to the social, ecological, and built infrastructure spheres of the park system. For JCOS, resilience is:

> ***The ability of Jefferson County Open Space to rebound, positively adapt to, or thrive amidst changing conditions or challenges – including social, environmental, and biological shocks or stressors.***

Planning for resiliency enables proactive, holistic management because it focuses on strategizing ways to build the capacity of the park system to cope with uncertainty and perpetually changing conditions. Resiliency planning acknowledges that the park system is dynamic, rather than static, and strives to work in tandem with this essential characteristic.

Planning for resiliency is different than planning for sustainability; where sustainability aims to continuously promote the same state of equilibrium in a system, resiliency looks for ways in which systems can reorganize in the face of uncertainty, shocks, or stressors, and yet still retain desirable functions. In other words, managing for sustainability focuses on maintaining balance at a fixed point, whereas managing for resiliency focuses on building the capacity of a system to adapt to change while still being able to maintain desirable functions.

Resiliency acknowledges uncertainty and that unforeseen events, including unexpected outcomes to management strategies, are bound to happen. By strengthening features that increase resilience in the park system, JCOS will further equip its organization and the resources it manages to positively rebound from, adapt to, and thrive amidst current and future change – all while maintaining desired functions.

Throughout the Framework, the following features are used to frame resilience for JCOS: diversity, connectivity,

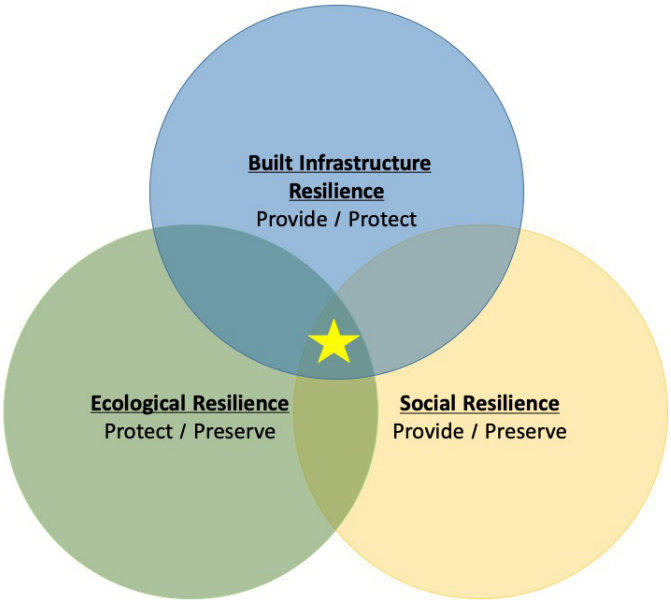


Figure 2: The three spheres of resiliency cover ecological, social, and built infrastructure elements of the JCOS park system. The star signifies where resiliency is maximized.

and redundancy (detailed in Sec. 3.1). These features can improve resiliency in the three identified spheres of the JCOS park system: social, ecological, and built infrastructure resilience.

1.3 Three Spheres of Resilience in JCOS

The three spheres of resilience defined by JCOS connect the social, ecological, and built infrastructure elements of the park system (Fig. 2). While these spheres support unique goals, they also intersect; by increasing one element's resiliency, the resilience of another element may be positively or negatively impacted. Proactively integrating the intersection of social, ecological, and built infrastructure resilience into plans and projects will support holistic management of the JCOS park system for the benefit of current and future generations.

1.3.1 Social Resilience

Social resilience is characterized by the provision of relevant nature-based experiences and the positive interactions of visitors with each other, the organization, and the natural and cultural environment of JCOS parks. Social resilience is measured by the following:

- A diversity of tangible and intangible experiences are relevant to a diversity of people including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities;
- Visitors feel safe participating in a diverse array of experiences;
- JCOS parks can be accessed through diverse means such as public transportation, walking, biking, and driving;
- Information is produced in a variety of ways relevant to a diversity of people including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities;
- All visitors feel connected to the mission of JCOS;
- All visitors feel welcome in JCOS parks;
- JCOS parks are accessible by all people including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities.

Ecosystem services are the benefits that humans freely gain from the environment. These include provisioning services (such as food, water, and energy); regulating services (such as flood control, carbon sequestration and air or water purification); cultural services (such as spiritual, therapeutic, and recreational benefits); and supporting services (such as nutrient cycling, primary production, and habitat provision).

1.3.2 Ecological Resilience

Ecological resilience is characterized by the protection of species and habitats found within the JCOS park system. It is important that ecological resilience considers the functional roles that specific species and habitats play in the larger landscape. Ecological resilience is thus measured by the following:

- ◊ A diversity of native species and associated habitats;
- ◊ A diversity of ecosystem services that are maintained and provided for the benefit of the public;
- ◊ Connectivity, either physical or functional, between parks, the surrounding landscape, and habitat patches within them.

1.3.3 Built Infrastructure Resilience

Built infrastructure resilience is characterized by the construction and maintenance of functioning, safe, and logically positioned features within the JCOS park system such as parking lots, restrooms, gathering spaces, and trails. Built infrastructure resilience is measured by the following:

- ◊ New or updated infrastructure connects to current and future infrastructure;
- ◊ Infrastructure plans and capital projects align with JCOS and/or relevant regional existing and future plans;
- ◊ Infrastructure plans and capital projects promote a sense of arrival congruent with other JCOS parks;
- ◊ Infrastructure such as trails enhance intuitive visitor use;
- ◊ Redundant structural health and safety measures provide adequate responses to shocks and stressors.

1.3.4 Intersection of Social, Ecological, and Built Infrastructure Resilience

As illustrated in Fig. 2, the three resilience spheres are not mutually exclusive and numerous interactions between them occur frequently within the JCOS park system. Plans, projects, and management strategies focused only on one or two spheres run the risk of ignoring other important dimensions of the organization. Ultimately, the *Preserve, Protect*, and *Provide* mission of JCOS is best accomplished at the intersection of social, ecological, and built infrastructure resilience.

For example, a property may be *preserved* and incorporated into the park system because of County residents' support for JCOS (social resilience), the presence of unique historical buildings (built infrastructure resilience), and its conservation value for priority species and habitats (ecological resilience). After acquisition, park and natural resources are *protected* by proactively developing a visitor carrying capacity (social resilience), repairing historic buildings (built infrastructure resilience), and controlling invasive species (ecological resilience). Once plans for public access are completed, healthy nature-based experiences may be *provided* on the property through visitor monitoring and management (social resilience), construction of recreational amenities such as trails and trailheads in appropriate locations (built infrastructure resilience), and interpretation of resources to encourage visitors to be good stewards of the land (ecological resilience).

The Scorecard, presented in Sec. 5 and Appendix C, encourages consideration of how plans, projects, and management strategies associated with one sphere may impact the plans, projects, and management strategies of the others.

Section 2
Shocks & Stressors

2. SHOCKS & STRESSORS

Maximizing resiliency in the JCOS park system will help reduce the impact of shocks and stressors. Shocks and stressors are not necessarily negative; they are merely disruptions to the system that require adaptations and proactive mitigation. The overarching goal of this Framework is to chart a path toward a resilient future in which JCOS's vulnerability to adverse changes and potential disasters is reduced, and the ability to rebound from and positively adapt to shocks and stressors is enhanced. This section describes the driving forces that make the JCOS park system vulnerable and identifies current shocks and stressors.

2.1 Definitions

The JCOS park system experiences a variety of shocks and stressors that can further increase the vulnerability of the system and lead to negative impacts on park visitors, infrastructure, and other resources. These terms are defined below:

- **Shocks** are direct disturbances. They are high intensity but low frequency events that disrupt the functions of a given system. Shocks include but are not limited to wildfire, flooding, extreme weather, and economic change.
- **Stressors** are indirect disturbances. They are underlying, long-term and recurring events that disrupt the functions of a given system and undermine the ability of that system to recover from or adapt to a shock. Stressors include but are not limited to drought, invasive species, changing recreation trends, and demographic shifts.

- **Vulnerabilities** arise when a system is exposed to a shock or stressor and is likely to suffer adverse effects from that shock or stressor. For example, prolonged drought may cause a forest to be more vulnerable to wildfire.
- **Consequences** are adverse impacts from shocks or stressors. For example, a catastrophic wildfire due to prolonged drought and fuel build up may have adverse impacts on forest health and visitor experiences.

Shocks and stressors within the JCOS park system also vary in their intensity and frequency. Most shocks are high intensity but low frequency events, while stressors are more variable (Fig. 3).

The shocks and stressors present in the JCOS park system are categorized as social, environmental, or biological, as described below. Examples of each category are provided in Table 1.

- **Social** shocks and stressors relate to human behavior.
- **Environmental** shocks and stressors relate to abiotic (non-living) factors.
- **Biological** shocks and stressors relate to biotic (living) factors.

The relationship between shocks and stressors is complex. Stressors can exacerbate the impact of shocks and can even cause shocks to occur. At the same time, individual or repeated shocks can create and exacerbate stressors. By formally incorporating resiliency into plans, projects, and management strategies, JCOS can reduce its vulnerability and better equip the park system to deal with current and future shocks and stressors.

Table 1: List of social, environmental, and biological shocks and stressors affecting the JCOS park system. These are subject to change over time.

SOCIAL	ENVIRONMENTAL	BIOLOGICAL
Changing Recreation Trends	Climate Change	Forest Pests
Demographic Shifts	Drought	Invasive Native & Non-Native Species
Economic Change	Flooding	Overgrazing & Overbrowsing
Population Growth	Fragmentation	Prairie Dogs
Increased Visitation	Light & Noise Pollution	
Visitor Behavior	Severe Weather Events	
Visitor Conflict	Wildfires	

SHOCKS AND STRESSORS IN JEFFERSON COUNTY OPEN SPACE

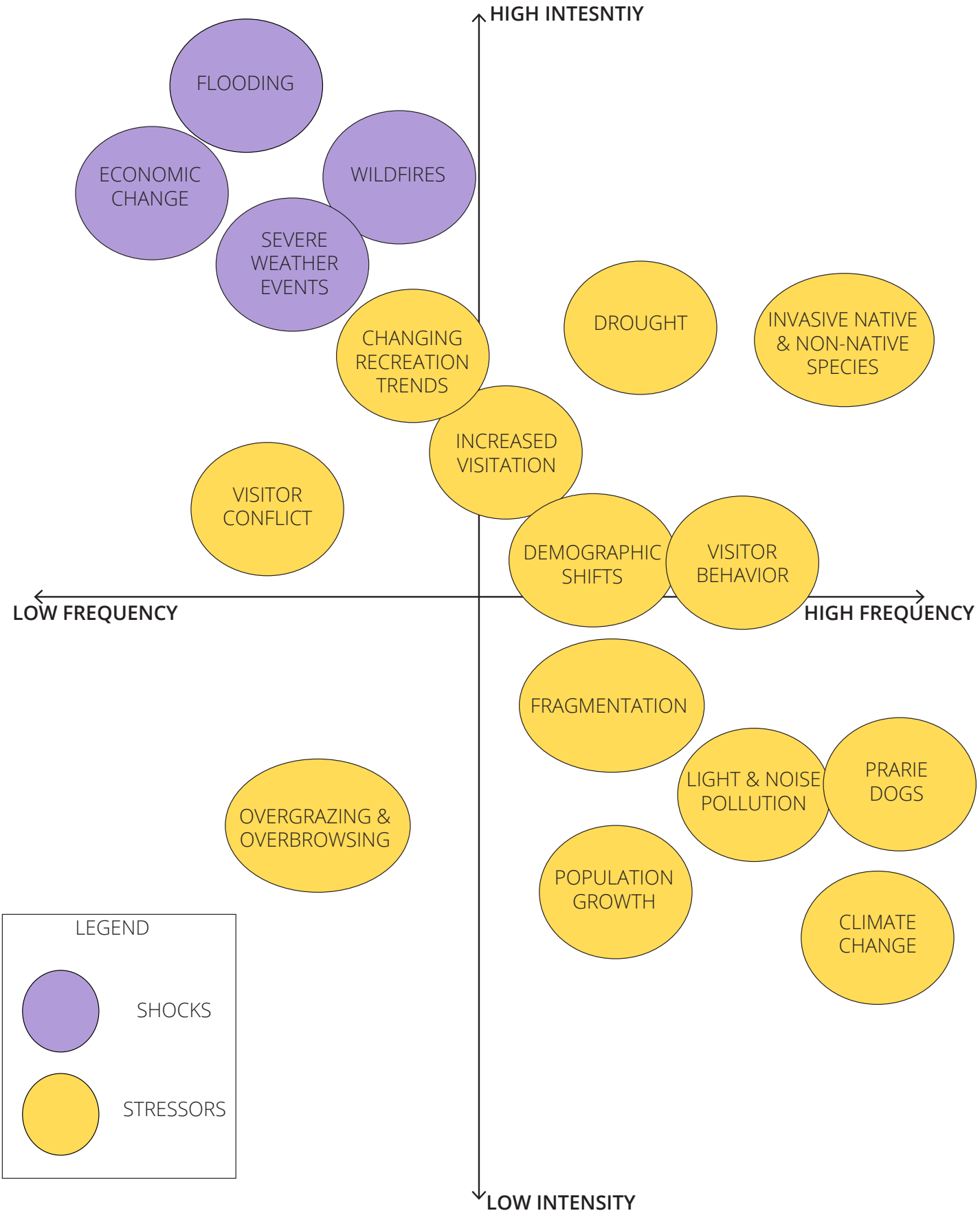


Figure 3: Shocks (purple) and stressors (yellow) in the JCOS park system illustrated on an intensity/frequency continuum.

Section 3
Vision of Resiliency

3. VISION OF RESILIENCY

Through a series of three workshops conducted in 2019, interdisciplinary groups of JCOS staff worked with MENV graduate students to envision a future (50-100 years from present) in which resiliency planning was strategically incorporated into organizational plans, projects, and management strategies – compared to a future without resiliency planning (Table 2). Some themes identified during these staff engagement workshops include: (1) the ability of the organization to meet its mission for the benefit of current and future generations despite changing conditions and (2) cultivating a large, interconnected system of conserved lands that are biologically diverse and support healthy, functioning ecosystems.

The features defined in Sec. 3.1 will help JCOS achieve its vision of a resilient park system.

3.1 Features of Resiliency

The Framework is grounded in three core features that make a resilient system: diversity, connectivity, and redundancy (Table 3). These features were selected based on a review of the academic literature on resilience and existing resiliency plans (Appendix E), as well as conversations with JCOS staff members and other relevant planning professionals and organizations.

By focusing on and managing for these features, the JCOS park system will better rebound from, positively adapt to, or thrive amidst the shocks and stressors described in Sec. 2.

Table 2: Compilation of 2019 workshops when JCOS staff collaborated with MENV graduate students to envision two contrasting future scenarios of the JCOS park system.

ENVISIONING A NON-RESILIENT PARK SYSTEM	ENVISIONING A RESILIENT PARK SYSTEM
Without deeper integration of resiliency into JCOS plans, projects, and management strategies, **the park system would experience an overall degradation of social, ecological, and built infrastructure resources.** JCOS may experience **habitat loss,** high risk of **wildfire, fragmented landscapes,** increased **visitor conflict, unsafe parking** conditions, **limited access** to parks, **increased undesignated trails,** and **too many designated trails.** Further consequences of not planning for resiliency may also include a **homogenous visitor base, limited public support** for the organization, and **unsafe visitor experiences** due to **exceeded park carrying capacities.**	**By strategically implementing resiliency planning** into JCOS plans, projects, and management strategies, **the park system will experience an improved ability to rebound from, positively adapt to, or thrive amidst shocks and stressors.** A resilient park system would allow **equitable access** to all visitor groups and have **increased multi-modal access** to JCOS parks. **Identified carrying capacities** would allow JCOS to develop balanced and holistic management strategies, and parks would be managed to **complement surrounding land managed by other agencies.** **Visitors would be well educated** about land stewardship and recreation etiquette; all social, ecological, and built infrastructure **resources would be protected and preserved;** and a **safe trail system** would be maintained. JCOS would continuously **plan with the future in mind.**

Table 3: Core features of resiliency serving as the basis for the Framework.

RESILIENCE FEATURE	DEFINITION	EXAMPLES
Diversity	Multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressors.	Diversity of native species Diversity of transportation options to access parks Diversity of visitor experiences Diversity of visitors
Connectivity	Physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the entire current and future JCOS park system.	Habitat connectivity Transportation connectivity Connected trail systems Partnerships between JCOS and neighboring public and private open space
Redundancy	Fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.	Redundant fail-safe mechanisms are built into infrastructure designs

Section 4
Existing Conditions

4. EXISTING CONDITIONS

The following section summarizes some of the key challenges and opportunities in the JCOS park system as the organization continues to work towards creating a more resilient future. This section is not intended to be a comprehensive review of the existing conditions specific to each JCOS park and property; rather, it is intended to shed light on overarching themes identified in the *Conservation Greenprint* and over the course of the three staff workshops conducted in 2019.

4.1 Challenges and Opportunities

Over recent years JCOS has experienced pressing challenges related to the social, ecological, and built infrastructure spheres of the park system. As outlined in the *Conservation Greenprint*, the following factors impact natural resources, visitor experiences, and built infrastructure.[2]

1. **Increased population growth:**

   With an estimated population growth rate of two percent per year in the Denver Metro Area and a visitation rate of about seven million people per year to their open space parks, JCOS is tasked with determining how to manage increased visitation and understanding carrying capacities of their park system. Even during weekdays, parking lots at trailheads are often at capacity and the trails are saturated with visitors.

2. **Proximity to the Denver Metro Area:**

   The JCOS park system is easily accessible to over three million people that reside in the Denver Metro Area. With a large local population and close proximity to Denver International Airport, the I-70 Mountain Corridor, and Red Rocks Park and Amphitheater, the organization is faced with the challenge of providing multi-modal access points for local and non-local visitors. Additionally, increased commercial and residential development adjacent to JCOS parkland pose challenges for managing the park system.

3. **Free access:**

   Outstanding public parks with a lack of entry fees make the JCOS system a popular place to recreate. Many residents of and visitors to the Denver Metro Area are outdoor enthusiasts, and JCOS parks offer a convenient way for visitors to have nature-based experiences free of charge.

4. **Demographic shifts:**

   As demographics in Jefferson County and the Denver Metro Area change, the opportunities provided by JCOS may need to adapt. Specifically, JCOS needs to consider how to provide nature-based experiences to the Latinx and age 65+ populations that have increased in recent years. Moreover, JCOS also needs to consider shifts in the following demographic groups: other minoritiy groups, youth, people with low socioeconomic status, and people with disabilities.

5. **A mature park system with aging infrastructure:**

   Infrastructure (e.g., parking lots, bathrooms, trail systems, etc.) within many JCOS parks are nearing the end of their lifecycle and will need to be replaced or improved to adapt to future recreation trends, environmental wear and tear, and increased, year-round visitation.

6. **Additional environmental or biological shocks or stressors:**

   JCOS parks, properties, and facilities are subject to an array of environmental and biological shocks and stressors that may negatively impact natural and cultural resources and degrade visitor experiences. These shocks and stressors are outlined in Sec. 2, Table 1.

Although these themes are not exhaustive, they reveal important factors influencing the park system. The specific challenges and opportunities identified by JCOS staff were integral components in shaping and influencing the Framework (Appendix B). The Framework does not prescribe explicit management strategies to address these challenges. Rather, the Scorecard is intended for staff to evaluate and prioritize plans, projects, and management strategies that JCOS may develop in response to these challenges and opportunities.

Section 5
The Resiliency Scorecard

5. THE RESILIENCY SCORECARD

The Scorecard, presented in Appendix C, is intended to serve as a decision making tool to complement existing ways in which JCOS teams may already be comparing, evaluating, and prioritizing projects. While the Scorecard is not meant to be the final decision making point on any plan, project, or management strategy, it is meant to bring together interdisciplinary teams to further integrate resiliency into decision making processes.

The first section of the Scorecard, "Risk," invites the evaluator to begin framing a project within resiliency. This section requires a qualitative evaluation of the shocks, stressors, vulnerabilities, and consequences (see Sec. 2.1 for definitions) associated with the project. Understanding the risk associated with a project is paramount before diving into the second section of the Scorecard, "Resilience Score." This section allows cross-comparison between projects based on how well they promote resiliency, which inherently helps mitigate risk.

The resilience score is calculated from a unique set of criteria tied to a resilience feature (diversity, connectivity, and redundancy). By assigning a quantitative value to a qualitative justification for each criterion, JCOS staff will be able to cross-compare projects based on how well they promote resiliency. The quantitative value (selected from a range of -3 to +3) indicates how well a project is expected to build out the identified resilience features. This scoring process is meant to capitalize on the knowledge and expertise of staff, and so this Framework and Scorecard do not provide detailed scoring guidelines. After evaluating a project's resilience score, the evaluator must additionally consider how the project will help JCOS adapt to relevant shocks and stressors. This supplementary section provides an opportunity for JCOS staff to understand how a project's resilience score will ultimately benefit the JCOS park system. This section also asks JCOS staff to consider three key questions pertinent to each sphere of resilience:

- How does the project promote diversity, equity and inclusivity?
- How does the project balance recreation with other ecosystem services?
- How does the project promote human health, safety, and wellbeing?

On the whole, the Scorecard is meant to capitalize on the knowledge and expertise of interdisciplinary JCOS staff and allow cross-comparison of plans, projects, and management strategies based on their ability to increase resiliency in the park system through diversity, connectivity, and redundancy in the social, ecological, and built infrastructure spheres of resilience.

Section 6
Resiliency in Action

6. RESILIENCY IN ACTION

Over recent years, JCOS has implemented successful resilience-focused projects with the hope of supporting positive responses to shocks and stressors.

6.1 Social Resilience - Designated Use Pilot Program

The JCOS system has over 244 miles of trails designated for hiking, cycling, and equestrian use. In 2018, a Jeffco Resident Survey determined 75% of respondents were in favor of designating trails for a single type of use. Shortly after, a one-year pilot program was established to evaluate the challenges and benefits associated with creating designated use trails. Trail segments of both White Ranch Park and Matthews/Winters Park have been designated as bike-only. Specifically, in June 2018 a middle segment of the Longhorn Trail at White Ranch Park was designated as a bike-only, one-way trail. The 2018 Jeffco Resident Survey results show that more than 80% of visitors were satisfied with this designation, and in June 2019 JCOS decided to make this change permanent. Additionally, in November 2018, the Dakota Ridge South Trail at Matthews/Winters Park was designated as bike-only with a mandatory clockwise direction.[3]

This pilot program is a noteworthy example of how JCOS increased resiliency within its park system. Improving the overall visitor experience through diversifying trail types increases social resiliency by reducing visitor conflict and enhancing visitor safety. In addition, the designated use trails reduce the need for pedestrians to yield to cyclists, therefore reducing the occurrence of stepping off-trail. As a result, native habitat is protected from trail widening and native plant species are protected from repeated footsteps, increasing overall ecological resilience in these parks.

6.2 Ecological Resilience - Forest Treatment at Flying J Ranch Park

Due to decades of fire suppression, changes in climate, and historic wildfires, forest resiliency and forest health in many areas of the JCOS park system are relatively low. Forests that were historically fire adapted and healthy are now overgrown and at risk of catastrophic wildfire, pest outbreaks, and drought. As a result, a 150-acre forest treatment (forest restoration and wildfire risk reduction project) was implemented in 2017 at Flying J Ranch Park, as a collaborative effort between JCOS, Denver Mountain Parks, and the Colorado State Forest Service. The project focused on reducing the densities of mixed conifer stands, promoting aspen stands, creating lodgepole regeneration patch cuts, and restoring ponderosa pine forests. Over time, this effort will create a landscape more resilient to catastrophic wildfire and insect damage by increasing the diversity of tree species, age classes, and distribution patterns

within the park. This project will also enhance visitor safety by removing hazardous trees around the main parking lot, the picnic area, and priority trail corridors. Strategically implementing projects such as these across forested areas of JCOS will increase ecological resilience across the park system.[4]

6.3 Built Infrastructure Resilience - The Big Easy Trailhead in Clear Creek Canyon Park

In collaboration with Great Outdoors Colorado (GOCO), Colorado Department of Transportation (CDOT), Clear Creek County Open Space, CEI Constructors, Stream Landscape Architecture and Planning, and Muller Engineering Company, JCOS has been a key player in the design and construction on a segment of the Peaks to Plains Trail since the spring of 2014. When completed, the entire Peaks to Plains Trail will comprise 65 miles along the corridor that follows Clear Creek from its headwaters at Loveland Pass on the Continental Divide, down to the confluence of the South Platte River north of Denver. The trail will span over four counties, seven cities, and one mile in elevation.

About 13.5 miles of the total Peaks to Plains Trail will be constructed within the boundaries of JCOS Clear Creek Canyon Park. The first portions of the trail opened between 2016-2017 and consist of four miles of a 10-foot wide concrete path with access points at the Big Easy Trailhead, Mayhem Gulch Trailhead, Cannonball Flats, and Oxbow Trailhead. This section of trail offers unique recreation experiences including the allowed use of bicycles in Clear Creek Canyon for the first time, increasing connectivity and recreation access points within the canyon.[5]

The Big Easy Trailhead opened in 2016 and has a variety of resilient features and amenities. A raised boardwalk protects sensitive riparian habitat (which is home to the federally endangered Preble's Meadow Jumping Mouse) from repeated visitor footsteps. Additionally, the boardwalk allows seasonal high water and ice to flow underneath, therefore increasing both built infrastructure and ecological resilience at this park. A geology garden, prospecting area, fishing platforms near the creek, picnic pavilions, and a wheelchair accessible trail promote social resilience by increasing the diversity of visitor experiences. A new parking lot containing 54 parking spaces for a diversity of vehicle types (including single occupancy, oversized, and handicap spots) increases access to the trailhead. Cor-Ten steel was used to construct the path's handrail, and the Vasquez Bridge was built with enough freeboard to withstand a 100-year event and abutments to withstand a 500-year scour event. Lastly, a stormwater quality and detention pond was installed next to the footpath as a mechanism to prevent trash and oils from entering Clear Creek and to absorb and hold excess rainwater during major stormwater events, increasing built infrastructure resilience at the Big Easy Trailhead.[6]

Section 7
Future Recommendations

7. FUTURE RECOMMENDATIONS

The following are a series of recommendations to achieve the vision of a resilient JCOS park system outlined in Sec. 3 of this Framework.

7.1 Collect baseline park data

One theme identified during staff engagement workshops was the need to collect more robust data throughout JCOS. Therefore, JCOS should identify data gaps and continue to strengthen the organization's quantitative, qualitative, and geospatial data collection and analysis to better inform decision making.

7.2 Identify park carrying capacities

A key element of resiliency planning is defining and identifying the carrying capacities for JCOS parks. This identification involves clearly defining the desired visitor experience and the current visitor demand for a park or trail system (such as a higher-density picnicking area, a network of predominantly mountain biking trails, or a more solitary, remote experience). Determining the carrying capacity of each experience will inform park carrying capacities. It also involves identifying the ecological carrying capacity of the park and the capacity of the available (or planned) infrastructure. Once identified, JCOS should explicitly write the carrying capacities into each Park Plan and include a stipulation for reevaluating carrying capacities on a feasible but regular basis.

7.3 Develop a comprehensive risk assessment analysis tool

The Scorecard involves a simple, *qualitative* risk assessment for proposed projects. In the future, this section should expand to include a more comprehensive and *quantitative* risk analysis. A comprehensive risk assessment tool would further enhance JCOS's suite of planning tools and help further refine project prioritization strategies.

A potential evaluation for risk may include the following:

- The probability of identified *shocks and stressors* occurring,
- The probability of *vulnerabilities* to *shocks and stressors,*
- And the *financial consequences* of *shocks, stressors, and vulnerabilities.*

7.4 Identify Key Performance Indicators (KPIs) and metrics of success for resiliency and monitor future projects

It is impossible to judge the success of plans, projects, and management strategies designed to increase the resiliency of JCOS without monitoring these projects. Therefore, JCOS should develop relevant KPIs and other metrics of success based on the organization's vision of resilience and priorities. These metrics will allow JCOS to assess ongoing projects, and the increased information and data available will help JCOS to make better decisions for future plans, projects, and management strategies.

7.5 Specifically engage underserved demographic groups

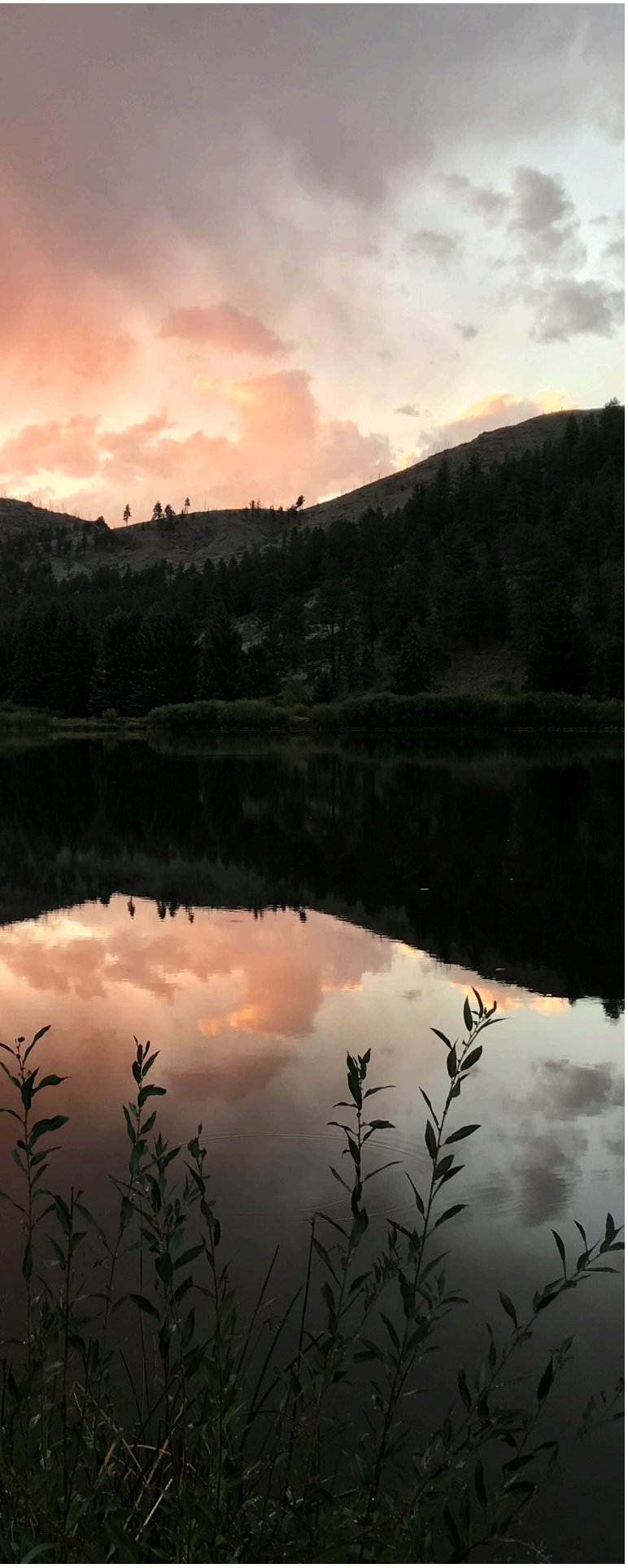
JCOS should continue to engage diverse and underserved visitor groups to build a broad coalition to foster stewardship in their parks. Education and intentional visitor engagement can develop strong connections to open space and lead to increased public stewardship. Engaging with diverse populations will create a more robust and engaged visitor base, which will increase resiliency from an ecological, social, and organizational standpoint.

7.6 Review resiliency Framework and related Scorecard every five years, and revise as necessary to match evolving JCOS conditions and goals

Conditions and goals of JCOS will change and evolve. Therefore, JCOS should review both the Framework and the Scorecard every five years, starting in 2025, to ensure that these documents remain consistent with changing conditions, and are relevant for future JCOS staff.

7.7 Develop appropriate weight factors for the Scorecard to match JCOS goals, priorities, and conditions.

In the current iteration, the Scorecard does not include weight factors for each of its criterion. However, incorporating weight factors into the Scorecard is necessary to have a robust decision making tool. Therefore, JCOS staff should collaborate to develop an appropriate weight factor for each criterion. These weight factors should be consistent with JCOS goals, priorities, and conditions identified in relevant strategic and park plans.



End Notes

1 “Conservation Greenprint,” Jefferson County Open Space, accessed August 21, 2019, https://www.jeffco.us/DocumentCenter/View/12971/Jeffco-Open-Space-Conservation-Greenprint?bidId=

2 “Conservation Greenprint,” Jefferson County Open Space, accessed October 12, 2019, https://www.jeffco.us/DocumentCenter/View/12971/Jeffco-Open-Space-Conservation-Greenprint?bidId=

3 “Designated Use,” Jefferson County Open Space. Accessed October 12, 2019. https://www.jeffco.us/3817/Designated-Use

4 “Forest Restoration and Wildlife Mitigation Flying J Ranch Park,” Jefferson County Open Space, last modified April 2019, https://www.jeffco.us/DocumentCenter/View/15033/Flying-J-Ranch-Park-Forest-Project-Fact-Sheet

5 “Clear Creek Canyon Park Peak to Plains Trail, Mouth of the Canyon Project,” Jefferson County Open Space, last modified January 2019, https://www.jeffco.us/DocumentCenter/View/16163/Peaks-to-Plains-Mouth-of-the-Canyon-Fact-Sheet

6 PeakstoPlains, “Big Easy Trailhead Open,” last modified October 2, 2019, https://peaks2plains.wordpress.com/category/big-easy/

APPENDIX A: GLOSSARY

Biological Shock/Stressor
Shocks and stressors that relate to biotic (living) factors.

Built Infrastructure Resilience
Characterized by the construction and maintenance of functioning, safe, and logically positioned features within the JCOS park system such as parking lots, restrooms, gathering spaces, and trails.

CDOT
Colorado Department of Transportation

Connectivity
Physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the entire current and future JCOS park park system.

Consequences
Adverse impacts from shocks and stressors.

CRF
Colorado Resiliency Framework

CRO
Colorado Resiliency Office

Diversity
Multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressors.

DOLA
Department of Local Affairs

Ecological Resilience
Characterized by the protection and preservation of species and habitats found within the JCOS park system.

Ecosystem Services
The benefits that humans freely gain from the environment. These include provisioning services (such as food, water, and energy); regulating services (such as flood control, carbon sequestration and air or water purification); cultural services (such as spiritual, therapeutic, and recreational benefits); and supporting services (such as nutrient cycling, primary production, and habitat provision).

Environmental Shock/Stressor
Shocks and stressors that relate to abiotic (non-living) factors.

GOCO
Great Outdoors Colorado

JCOS
Jefferson County Open Space

KPI
Key Performance Indicators

MENV
Masters of the Environment

Redundancy
Fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.

Resilience/Resiliency
The ability of Jefferson County Open Space to rebound, positively adapt to, or thrive amidst changing conditions or challenges – including social, environmental, and biological shocks or stressors.

Shocks
Direct disturbances consisting of high intensity but low frequency events that disrupt the functions of a given system.

Social Resilience
Characterized by the provision of relevant nature-based experiences and the positive interactions of visitors with each other, the organization, and the natural and cultural environment of JCOS parks.

Social Shock/Stressor
Shocks and stressors that relate to human behavior.

Stressors
Indirect disturbances consisting of underlying, long-term and recurring events that disrupt the functions of a given system and undermine the ability of a system to recover from or adapt to a shock.

Vulnerabilities
Arise when a system is exposed to a shock or stressor and is likely to suffer adverse effects from that shock or stressor.

This page is intentionally left blank.

APPENDIX B: STAFF WORKSHOP RESULTS

Over the course of summer 2019 three workshops were conducted with JCOS staff members in order to develop a vision of a resilient JCOS park system. These workshops involved identifying relevant shocks and stressors affecting JCOS parks, management challenges and opportunities, and collecting ideas and receiving feedback in order to co-create the Scorecard. Each workshop was focused on a different sphere of resilience: the first on ecological resilience, the second on built infrastructure resilience, and the third on social resilience.

At each workshop JCOS staff members participated in a World Cafe exercise. During this activity, several questions were posted on pieces of flip-chart paper around the room, and staff members were encouraged to walk around the room and answer these questions. The questions were designed to get a sense of how staff view their jobs in relation to the sphere of resilience discussed during that session; to identify different management challenges the staff faces and where they see opportunities for implementing resiliency planning; and to gather information to develop a vision statement of resiliency for JCOS.

Questions from the Ecological Workshop ("Preserve"):

1. *What ecological resources does your team preserve?*
2. *What ecological management challenges do you face?*
3. *What ecological resources ought to be preserved on open space property?*
4. *Envisioning the future [3 flip charts divided in 2]: What could the open space system look like in 10 years? 50 years? 100 years? [Status quo and resilient]*

Questions from the Built Infrastructure Workshop ("Protect"):

1. *What built infrastructure resources does your team protect?*
2. *What built infrastructure management challenges do you face?*
3. *What built infrastructure management opportunities do you have?*
4. *What built infrastructure resources ought to be protected on open space property?*
5. *Envisioning the future [3 flip charts divided in 2]: What could the open space system look like in 10 years? 50 years? 100 years? [Status quo and resilient]*

Questions from the Social Workshop ("Provide"):

1. *What social resources does your team provide?*
2. *What social management challenges do you face?*
3. *What social management opportunities do you have?*
4. *What social resources ought to be provided on open space property?*
5. *Envisioning the future [3 flip charts divided in 2]: What could the open space system look like in 10 years? 50 years? 100 years? [Status quo and resilient]*

After this exercise participants were brought back together for a facilitated discussion about responses to the questions. These conversations lent valuable insight into how JCOS operates and the organization's needs regarding the Framework and Scorecard. All data from the three workshops were coded and analyzed in order to identify and define major themes, management opportunities, and challenges. The analysis is presented in Table 4.

Table 4: Themes, management opportunities, and management challenges identified during workshops with JCOS staff.

THEMES	DESCRIPTION	OPPORTUNITIES	CHALLENGES
Access	The accessibility of JCOS parks, experiences, and information for all visitors.	Providing relevant and diverse experiences for changing visitor demographics	Complying with ADA policies Managing undesignated trails
Administration	JCOS organizational and funding structures and needs.	Formally prioritizing goals for managing parks and properties Implementing data collection and analysis strategies	Identifying and filling data gaps and needs
Balance	The balance between the JCOS mission of Provide, Protect, Preserve.	Implementing innovative planning, design, and management strategies	Increasing public demand for trails and expanded recreation opportunities
Communication	JCOS-provided information as it relates to visitor behavior and knowledge of JCOS rules and regulations.	Utilizing new technology such as social media to reach diverse audiences Improving information on suitable times for park visitation based on season, trail conditions, and use	Understanding how to communicate with and reach diverse visitors
Connectivity	The connectivity of ecological, recreation (i.e., trails), other infrastructure, management, and transportation systems within and to JCOS parks and the region.	Unifying messaging with adjacent public land managers Designing new transportation networks between and within parks	Addressing habitat fragmentation
Data	The availability of quantitative, qualitative, and geospatial data to inform decisions at JCOS.	Defining and identifying carry capacities for each JCOS park and property Utilizing new technologies for collecting data Integrating 2020 Census data into GIS analyses	Collecting data Defining and filling data gaps
Education	JCOS-provided educational programming as it relates to visitor behavior and knowledge/stewardship of JCOS resources.	Providing environmental, stewardship, and historical education opportunities to all park visitors in diverse ways	Reaching visitors about land stewardship and trail etiquette Managing visitor conflicts
Partnerships	Community and intergovernmental collaboration and alignment of management/ communication strategies.	Increasing research collaborations with relevant agencies and organizations	Fostering partnerships with private landowners regarding land preservation and access

THEMES	DESCRIPTION	OPPORTUNITIES	CHALLENGES
Policy	Top-down Jefferson County policy and funding (e.g., zoning).	Purchasing/retaining water rights Acquiring land for JCOS	Engaging JCOS staff and the public regarding new policies in Jefferson County, as they relate to the open space organization
Preservation	The preservation of all social, ecological, and built infrastructure resources within the JCOS system.	Integrating resilience planning into JCOS plans, projects, and management strategies Engaging the public about land stewardship	Balancing the "protect and preserve" and "provide" parts of the JCOS mission Managing for increased population in the Denver Metro Area and at JCOS parks
Proactive & Innovative Planning/Design	Strategies taken to improve JCOS functioning of social, ecological, and built infrastructure resiliency.	Developing single-use and directional trails Building out and/or supporting alternative transportation options to and within JCOS parks Generating solar energy from infrastructure Organization-wide LEED certfication Conducting pilot projects Revamping park planning and decision making processes	Long-term planning/planning for future generations Improving and retrofitting aging infrastructure
Public Opinion	Public support for JCOS.	Enhancing public engagement with the organization Defining the economic impact of JCOS to the surrounding community	Balancing the needs of special interest groups and the mission of JCOS
Visitation Growth	Visitation growth and concern for crowding at JCOS parks.	Increasing the scope and diversity of public engagement and education	Managing impacts from increasing visitation to JCOS resources Managing full parking lots that lead to parking overflow into neighborhoods and unsafe road shoulders
Visitor Safety	The perceived and real safety of JCOS park visitors.	Increasing the resiliency of JCOS parks and properties to cope with shocks and stressors	The unexpected occurrence of shocks and stressors

APPENDIX C: THE RESILIENCY SCORECARD

Jefferson County Open Space Resiliency Scorecard	
Project name:	
Project description:	

Project Resilience Score:		**Scoring Range: -39 to +39**

Section 1: Risk	**Please identify the relevant shocks and stressors, vulnerabilities, and consequences associated with this project.**
Shocks *Direct disturbances*	
Stressors *Indirect distrurbances*	
Vulnerabilities *Arise when a system is exposed to a shock or stressor and is likely to suffer adverse effects from that shock or stressor*	
Consequences *Adverse impacts from shocks and stressors*	

Section 2: Resilience Score

Diversity: To what degree does this project impact diversity within the JCOS park system?

Multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressors.

Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	***Please provide a detailed justification for this score. Consider both short and long term impacts of the project:***
Visitor Experiences *A diversity of tangible and intangible experiences relevant to a diverse population including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities; Visitors feel safe participating in a diverse array of experiences*		*Project significantly reduces the diversity of visitor experiences*	*Project moderately reduces the diversity of visitor experiences*	*Project mildly reduces the diversity of visitor experiences*	*Project does not affect the diversity of visitor experiences*	*Project mildly promotes the diversity of visitor experiences*	*Project moderately promotes the diversity of visitor experiences*	*Project significantly promotes the diversity of visitor experiences*	
Transportation Access *JCOS parks can be accessed through diverse means such as public transportation, walking, biking, and driving*		*Project significantly reduces the diversity of transportation access*	*Project moderately reduces the diversity of transportation access*	*Project mildly reduces the diversity of transportation access*	*Project does not affect the diversity of transportation access*	*Project mildly promotes the diversity of transportation access*	*Project moderately promotes the diversity of transportation access*	*Project significantly promotes the diversity of transportation access*	
Information Production & Distribution *Information is produced and distributed to a variety of ways relevant to a diverse population including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities*		*Project significantly reduces the diversity of information production and distribution*	*Project moderately reduces the diversity of information production and distribution*	*Project mildly reduces the diversity of information production and distribution*	*Project does not affect the diversity of information production and distribution*	*Project mildly promotes the diversity of information production and distribution*	*Project moderately promotes the diversity of information production and distribution*	*Project significantly promotes the diversity of information production and distribution*	
Native Species *A species or organism that occurs naturally within a region*		*Project significantly reduces the diversity of native species*	*Project moderately reduces the diversity of native species*	*Project mildly reduces the diversity of native species*	*Project does not affect the diversity of native species*	*Project mildly promotes the diversity of native species*	*Project moderately promotes the diversity of native species*	*Project significantly promotes the diversity of native species*	
Habitats *The area or natural environment in which an organism or population normally lives or grows*		*Project significantly reduces habitat diversity*	*Project moderately reduces habitat diversity*	*Project mildly reduces habitat diversity*	*Project does not affect habitat diversity*	*Project mildly promotes habitat diversity*	*Project moderately promotes habitat diversity*	*Project significantly promotes habitat diversity*	
Ecosystem Services *The benefits that humans freely gain from the environment. These include provisioning services, regulating services, cultural services and supporting services.*		*Project significantly reduces ecosystem services*	*Project moderatey reduces ecosystem services*	*Project mildly reduces ecosystem services*	*Project does not affect ecosystem services*	*Project mildly promotes ecosystem services*	*Project moderately promotes ecosystem services*	*Project significantly promotes ecosystem services*	
Diversity Score:	0								

Connectivity: To what degree does this project impact connectivity within the JCOS park system?									
Physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the current and future JCOS system									
Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	*Please provide a detailed justification for this score. Consider both short and long term impacts of the project:*
Personal Experience *Visitors feel welcome in JCOS parks and feel connected to the JCOS mission*		*Project significantly reduces personal/ experiential connectedness*	*Project moderately reduces personal/ experiential connectedness*	*Project mildly reduces personal/ experiential connectedness*	*Project does not affect personal/ experiential connectedness*	*Project mildly promotes personal/ experiential connectedness*	*Project moderately promotes personal/ experiential connectedness*	*Project significantly promotes personal/ experiential connectedness*	
Equitable Access *JCOS parks are accessible by all people including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities.*		*Project significantly reduces equitable access*	*Project moderately reduces equitable access*	*Project mildly reduces equitable access*	*Project does not affect equitable access*	*Project mildly promotes equitable access*	*Project moderately promotes equitable access*	*Project significantly promotes equitable access*	
Ecosystem *Either physical or functional connectedness between parks, the surrounding landscape, and/or habitat patches within them*		*Project significantly reduces ecosystem connectivity*	*Project moderately reduces ecosystem connectivity*	*Project mildly reduces ecosystem connectivity*	*Project does not affect ecosystem connectivity*	*Project mildly promotes ecosystem connectivity*	*Project moderately promotes ecosystem connectivity*	*Project significantly promotes ecosystem connectivity*	
Infrastructure *The degree to which proposed infrastructure connects to current and future infrastructure*		*Project significantly reduces infrastructure connectivity*	*Project moderately reduces infrastructure connectivity*	*Project mildly reduces infrastructure connectivity*	*Project does not affect infrastructure connectivity*	*Project mildly promotes infrastructure connectivity*	*Project moderately promotes infrastructure connectivity*	*Project significantly promotes infrastructure connectivity*	
Planning & Management *The degree to which the project aligns with JCOS and/or relevant regional existing and future plans*		*Project significantly reduces alignment with JCOS/regional planning & management*	*Project moderately reduces alignment with JCOS/regional planning & management*	*Project mildly reduces alignment with JCOS/regional planning & management*	*Project does not affect alignment with JCOS/regional planning & management*	*Project mildly promotes alignment with JCOS/regional planning & management*	*Project moderately promotes alignment with JCOS/regional planning & management*	*Project significantly promotes alignment with JCOS/regional planning & management*	
Design *The degree to which the project promotes a sense of arrival congruent with other JCOS parks; the degree to which the project enhances intuitive visitor use*		*Project significantly reduces design connectivity*	*Project moderately reduces design connectivity*	*Project mildly reduces design connectivity*	*Project does not affect design connectivity*	*Project mildly promotes design connectivity*	*Project moderately promotes design connectivity*	*Project significantly promotes design connectivity*	
Connectivity Score:	0								

Redundancy: To what degree does this project impact redundancy within the JCOS park system?									
Fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.									
Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	*Please provide a detailed justification for this score. Consider both short and long term impacts of the project:*
Structural Health & Safety Measures *The degree to which structural health and safety measures are present*		*Project significantly reduces the existence of fail safes*	*Project moderately reduces the existence of fail safes*	*Project mildly reduces the existence of fail safes*	*Project does not affect the existence of fail safes*	*Project mildly promotes the existence of fail safes*	*Project moderately promotes the existence of fail safes*	*Project significantly promotes the existence of fail safes*	
Redundancy Score:	0								

Section 3: How does this project allow JCOS to be more adaptive to relevant social, ecological, or biological shocks and stressors? **Consider how the project promotes diversity, equity, and inclusivity; balances recreation and other ecosystem services; and promotes human health, safety, and wellbeing.**

Term	Definition
Built Infrastructure Resilience	Characterized by the construction and maintenance of functioning, safe, and logically positioned features within the JCOS park system such as parking lots, restrooms, gathering spaces, and trails.
Connectivity	Physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the entire current and future JCOS park park system.
Consequences	Adverse impacts from shocks and stressors.
Diversity	Multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressorss
Ecological Resilience	Characterized by the protection and preservation of species and habitats found within the JCOS park system.
Ecosystem Services	The benefits that humans freely gain from the environment. These include provisioning services (such as food, water, and energy); regulating services (such as flood control, carbon sequestration and air or water purification); cultural services (such as spiritual, therapeutic, and recreational benefits); and supporting services (such as nutrient cycling, primary production, and habitat provision).
Redundancy	Fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.
Shocks	Direct disturbances consisting of high intensity but low frequency events that disrupt the functions of a given system.
Social Resilience	Characterized by the provision of relevant nature-based experiences and the positive interactions of visitors with each other, the organization, and the natural and cultural environment of JCOS parks.
Stressors	Indirect disturbances consisting of underlying, long-term and recurring events that disrupt the functions of a given system and undermine the ability of a system to recover from or adapt to a shock.
Vulnerabilities	Arise when a system is exposed to a shock or stressor and is likely to suffer adverse effects from that shock or stressor.

This page is intentionally left blank.

APPENDIX D: HYPOTHETICAL RESILIENCY SCORECARD EXAMPLE

Jefferson County Open Space Resiliency Scorecard	
Project name:	The Big Easy Trailhead (within Clear Creek Canyon Park)
Project description:	Adding another .75 miles to the Peaks to Plains Trail, the Big Easy Trailhead and recreation area has a permanent restroom, 54 parking spaces, fishing platforms over the water, picnic pavilions, a geology garden, and a boardwalk in areas where vegetation needs to be protected. A new bridge also spans the creek, leading onto the Peaks to Plains Trail, which connects to the Mayhem Gulch trailhead westward up the canyon. This project also establishes new stormwater management projects to enhance water quality and prevent erosion.

Project Resilience Score:	**30**	**Scoring Range: -39 to +39**

Section 1: Risk	**Please identify the relevant shocks and stressors, vulnerabilities, and consequences associated with this project.**
Shocks *Direct disturbances*	Flooding, wildfires, severe weather events, economic change, etc.
Stressors *Indirect distrurbances*	Population growth, increased visitation, changing recreation trends and visitor demographics, drought, visitor conflict, invasive native and non-native species, climate change, noise pollution, etc.
Vulnerabilities *Arise when a system is exposed to a shock or stressor and is likely to suffer adverse effects from that shock or stressor*	Infrastructure integrity, endangered and threatened species, water quality, recreation opportunities, etc.
Consequences *Adverse impacts from shocks and stressors*	Infrastructure failures, impacts to wildlife and plants, streambank erosion, lack of visitor safety, lack of healthy, nature-based experiences, etc.

Section 2: Resilience Score

Diversity: To what degree does this project impact diversity within the JCOS park system?

Multiple, unique components of a system that serve similar functions – therefore enabling diverse responses to shocks and stressors.

Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	***Please provide a detailed justification for this score. Consider both short and long term impacts of the project:***
Visitor Experiences *A diversity of tangible and intangible experiences relevant to a diverse population including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities; Visitors feel safe participating in a diverse array of experiences*	3	*Project significantly reduces the diversity of visitor experiences*	*Project moderately reduces the diversity of visitor experiences*	*Project mildly reduces the diversity of visitor experiences*	*Project does not affect the diversity of visitor experiences*	*Project mildly promotes the diversity of visitor experiences*	*Project moderately promotes the diversity of visitor experiences*	*Project significantly promotes the diversity of visitor experiences*	Prospecting, picnicking, hiking, walking, biking, fishing, education (geology garden), whitewater sports, close to Mayhem Gulch Trailhead offer a diverse array of visitor experiences catering to a diverse visitor crowd.
Transportation Access *JCOS parks can be accessed through diverse means such as public transportation, walking, biking, and driving*	2	*Project significantly reduces the diversity of transportation access*	*Project moderately reduces the diversity of transportation access*	*Project mildly reduces the diversity of transportation access*	*Project does not affect the diversity of transportation access*	*Project mildly promotes the diversity of transportation access*	*Project moderately promotes the diversity of transportation access*	*Project significantly promotes the diversity of transportation access*	Short term - The park is only accessible via personal vehicle. Long term - The park will ultimately be accessible via cycling and walking from other areas of Clear Creek Canyon. This project does not address other multimodal transportation options.
Information Production & Distribution *Information is produced and distributed to a variety of ways relevant to a diverse population including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities*	1	*Project significantly reduces the diversity of information production and distribution*	*Project moderately reduces the diversity of information production and distribution*	*Project mildly reduces the diversity of information production and distribution*	*Project does not affect the diversity of information production and distribution*	*Project mildly promotes the diversity of information production and distribution*	*Project moderately promotes the diversity of information production and distribution*	*Project significantly promotes the diversity of information production and distribution*	Information about this project is posted on the JCOS website and on other online news sites. General JCOS information is minimally available besides a trail map and the geology garden.
Native Species *A species or organism that occurs naturally within a region*	2	*Project significantly reduces the diversity of native species*	*Project moderately reduces the diversity of native species*	*Project mildly reduces the diversity of native species*	*Project does not affect the diversity of native species*	*Project mildly promotes the diversity of native species*	*Project moderately promotes the diversity of native species*	*Project significantly promotes the diversity of native species*	The project supports a wide array of native species, including the endangered Preble's Meadow Jumping Mouse.
Habitats *The area or natural environment in which an organism or population normally lives or grows*	2	*Project significantly reduces habitat diversity*	*Project moderately reduces habitat diversity*	*Project mildly reduces habitat diversity*	*Project does not affect habitat diversity*	*Project mildly promotes habitat diversity*	*Project moderately promotes habitat diversity*	*Project significantly promotes habitat diversity*	The project protects a variety of riparian and forested areas.
Ecosystem Services *The benefits that humans freely gain from the environment. These include provisioning services, regulating services, cultural services and supporting services.*	2	*Project significantly reduces ecosystem services*	*Project moderatey reduces ecosystem services*	*Project mildly reduces ecosystem services*	*Project does not affect ecosystem services*	*Project mildly promotes ecosystem services*	*Project moderately promotes ecosystem services*	*Project significantly promotes ecosystem services*	The project provides stormwater management, the retaining wall prevents erosion, and ample recreation opportunities support human health, safety, and well-being.
Diversity Score:	12								

Connectivity: To what degree does this project impact connectivity within the JCOS park system?									
Physical or functional patterning that supports continuity of resources, experiences, and infrastructure – therefore allowing management strategies to consider the current and future JCOS system									
Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	*Please provide a detailed justification for this score. Consider both short and long term impacts of the project:*
Personal Experience *Visitors feel welcome in JCOS parks and feel connected to the JCOS mission*	3	*Project significantly reduces personal/ experiential connectedness*	*Project moderately reduces personal/ experiential connectedness*	*Project mildly reduces personal/ experiential connectedness*	*Project does not affect personal/ experiential connectedness*	*Project mildly promotes personal/ experiential connectedness*	*Project moderately promotes personal/ experiential connectedness*	*Project significantly promotes personal/ experiential connectedness*	All types of visitors will feel welcome through diverse recreation opportunities including accessible trails. The geology garden allows visitors to feel connected to the JCOS mission of protecting natural resources.
Equitable Access *JCOS parks are accessible by all people including the Latinx community and other minorities, youth, visitors 65+, people with low socioeconomic status, and people with disabilities.*	2	*Project significantly reduces equitable access*	*Project moderately reduces equitable access*	*Project mildly reduces equitable access*	*Project does not affect equitable access*	*Project mildly promotes equitable access*	*Project moderately promotes equitable access*	*Project significantly promotes equitable access*	All types of visitors can enjoy this recreation area, however, access requires a personal vehicle or a long walk/bike ride to access.
Ecosystem *Either physical or functional connectedness between parks, the surrounding landscape, and/or habitat patches within them*	1	*Project significantly reduces ecosystem connectivity*	*Project moderately reduces ecosystem connectivity*	*Project mildly reduces ecosystem connectivity*	*Project does not affect ecosystem connectivity*	*Project mildly promotes ecosystem connectivity*	*Project moderately promotes ecosystem connectivity*	*Project significantly promotes ecosystem connectivity*	The project does not impede the flowing river system, and the bridge connects the north and south portions of the park to allow wildlife crossings.
Infrastructure *The degree to which proposed infrastructure connects to current and future infrastructure*	3	*Project significantly reduces infrastructure connectivity*	*Project moderately reduces infrastructure connectivity*	*Project mildly reduces infrastructure connectivity*	*Project does not affect infrastructure connectivity*	*Project mildly promotes infrastructure connectivity*	*Project moderately promotes infrastructure connectivity*	*Project significantly promotes infrastructure connectivity*	This project contains resilient infrastructure including bridge abutments, a stormwater detention pond, cor-ten steel, a boardwalk, pedestrian viewpoints on the bridge, and bathrooms.
Planning & Management *The degree to which the project aligns with JCOS and/or relevant regional existing and future plans*	3	*Project significantly reduces alignment with JCOS/regional planning & management*	*Project moderately reduces alignment with JCOS/regional planning & management*	*Project mildly reduces alignment with JCOS/regional planning & management*	*Project does not affect alignment with JCOS/regional planning & management*	*Project mildly promotes alignment with JCOS/regional planning & management*	*Project moderately promotes alignment with JCOS/regional planning & management*	*Project significantly promotes alignment with JCOS/regional planning & management*	The Trailhead connects into other trailheads in Clear Creek Canyon Park (via the Peaks to Plains trail) and includes a picnic and bathroom.
Design *The degree to which the project promotes a sense of arrival congruent with other JCOS parks; the degree to which the project enhances intuitive visitor use*	3	*Project significantly reduces design connectivity*	*Project moderately reduces design connectivity*	*Project mildly reduces design connectivity*	*Project does not affect design connectivity*	*Project mildly promotes design connectivity*	*Project moderately promotes design connectivity*	*Project significantly promotes design connectivity*	The design helps with the intuitive use of the park, including adequate wayfinding. The trailhead is recognizable as a JCOS park.
Connectivity Score:	15								

Redundancy: To what degree does this project impact redundancy within the JCOS park system?									
Fail-safe mechanisms that ensure if a component of a system fails, another component may take its place – therefore promoting adequate responses to shocks and stressors.									
Criteria	**Score (-3 to +3)**	**Scoring Guidelines**							
		-3	**-2**	**-1**	**0**	**1**	**2**	**3**	*Please provide a detailed justification for this score. Consider both short and long term impacts of the project:*
Structural Health & Safety Measures *The degree to which structural health and safety measures are present*	3	*Project significantly reduces the existence of fail safes*	*Project moderately reduces the existence of fail safes*	*Project mildly reduces the existence of fail safes*	*Project does not affect the existence of fail safes*	*Project mildly promotes the existence of fail safes*	*Project moderately promotes the existence of fail safes*	*Project significantly promotes the existence of fail safes*	The Vasquez Bridge connects the Big Easy Trailhead to the Peak to Plains Trail across Clear Creek. The bridge was constructed with enough freeboard made to withstand a 100 year event and abutments are built to withstand a 500 year scour event.
Redundancy Score:	3								

Section 3: How does this project allow JCOS to be more adaptive to relevant social, ecological, or biological shocks and stressors?
Consider how the project promotes diversity, equity, and inclusivity; balances recreation and other ecosystem services; and promotes human health, safety, and wellbeing.

The raised boardwalk protects sensitive riparian habitat (which is home to the federally endangered Preble's Meadow Jumping Mouse) from repeated visitor footsteps. Additionally, the boardwalk allows seasonal high water and ice to flow underneath, therefore increasing both built infrastructure and ecological resilience at this park. The geology garden, prospecting area, fishing platforms near the creek, picnic pavilions, and a wheelchair accessible trail promote social resilience by increasing the diversity of visitor experiences. The new parking lot containing 54 parking spaces for a diversity of vehicle types (including single occupancy, oversized, and handicap spots) increases access to the trailhead. Cor-Ten steel was used to construct the path's handrail, and the Vasquez Bridge was built with enough freeboard to withstand a 100-year event and abutments to withstand a 500-year scour event. Lastly, the stormwater quality and detention pond was installed next to the footpath as a mechanism to prevent trash and oils from entering Clear Creek and to absorb and hold excess rainwater during major stormwater events, increasing built infrastructure resilience at the Big Easy Trailhead.

This page is intentionally left blank.

APPENDIX E: LITERATURE REVIEW

I. What is Resilience?

Ecologists began developing resilience theory in the 1960s in order to understand the unexpected linkages and dynamics found in complex systems.[1] Many of the ideas associated with resilience theory are closely related to systems thinking, as they interpret the ability of a system to respond to changes in its surrounding environment. In her book *Thinking in Systems: A Primer*, Donella Meadows even notes that one of the characteristics of a high-functioning system is resilience.[2] A system is an interconnected set of things, such as an ecosystem or social institution, that develops its own pattern of behavior (often referred to as the system's "function" or "purpose"), and has a characteristic response to outside influences.[3] These outside influences are often referred to as disturbances, stressors, or shocks. Disturbances refer to temporary changes in environmental conditions that have long-term impacts to a system's stability, while stressors refer to long-term pressures that reduce a system's stability such as the migration of invasive species or a slow decline in economic growth.[4] Shocks refer to short-term changes with immediate impacts to a system's stability such as wildfire, flood, or economic crashes. Historically, ecological resilience theory was focused on interpreting the stability of ecosystems and held that if resilient, ecosystems could return to a single point of stability or equilibrium after a disturbance, stressor, or shock.[5] These assumptions gave rise to such land management concepts as maximum sustained yield and optimal control of harvest.[6]

To that end, in his 1973 essay, "Resilience and Stability of Ecological Systems," Holling uses resilience theory to describe aspects of change in an ecosystem over time.[7] He describes resilience as, "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables."[8] This concept of resilience recognizes that systems can organize at multiple points of stability while still maintaining the same purpose or function, as opposed to earlier assumptions that an ecosystem can only hold a single state of equilibrium. This concept of resilience emphasizes determining the level of disturbance a system can withstand before shifting into an "alternative configuration," or rather a system with a new function.[9] In the early 2000s, ecologists further interpreted that resilience does not require a system to have a single stable point, but rather a stable trajectory that progressively reinforces itself.[10] That is, modern resilience theory considers that systems may change their organizational processes and even look surprisingly different at times, yet still retain the same function. This ability for a system to alter its organization yet retain the same function is also known as adaptive capacity.[11] When a system lacks adaptive capacity, it is no longer able to absorb a disturbance and thus moves into a new "stability domain," or rather a system with a new, less desirable function.[12] Adaptive capacity can be strengthened if a system integrates "aspects of change, reorganization, [and] learning" into responses to changing conditions, shocks, and stressors.[13]

1 Lance H. Gunderson and Craig R. Allen, Introduction to *Foundations of Ecological Resilience,* ed. Lance H. Gunderson, Craig R. Allen and C.S. Holling (Washington: Island Press, 2010), *xiii-xxv.*
2 Donella H. Meadows, *Thinking in Systems: A Primer,* ed. Diana Wright (London: Earthscan, 2009), 75.
3 Meadows, *Thinking in Systems*, 2, 188.
4 Resilience Measurement Technical Working Group, "Measuring Shocks and Stressors as Part of Resilience Measurement," Food Security Information Network Technical Series No. 5, September 2015, http://www.fsincop.net/fileadmin/user_upload/fsin/docs/resources/1_FSIN_TechnicalSeries_5.pdf.
5 Gunderson and Allen, *Foundations of Ecological Resilience,* xiv.
6 Gunderson and Allen, *Foundations of Ecological Resilience,* xv.
7Gunderson and Allen, *Foundations of Ecological Resilience,* xv.
8 C.S. Holling, "Resilience and Stability of Ecological Systems," in *Foundations of Ecological Resilience*, ed. Lance H. Gunderson, Craig R. Allen and C.S. Holling, (Washington: Island Press, 2010), 19-49.
9 Gunderson and Allen, *Foundations of Ecological Resilience,* xv.
10 Lance H. Gunderson, C.S. Holling, Lowell Pritchard Jr., and Garry D. Peterson, "Resilience of Large Scale Resource Systems," in *Resilience and the Behavior of Large-Scale Systems*, ed. Lance H. Gunderson and Lowell Pritchard Jr., (Washington: Island Press 2002), 14.
11Lance H. Gunderson, Lowell Pritchard Jr., C.S. Holling, Carl Folke, and Garry D. Peterson, "A Summary and Synthesis of Resilience in Large-Scale Systems," in *Resilience and the Behavior of Large-Scale Systems,* e. Lance H. Gunderson and Lowell Pritchard Jr., (Washington: Island Press 2002), 264.
12 Lance H. Gunderson and Carl J. Waters, "Resilience in Wet Landscapes of Southern Florida," in *Resilience and the Behavior of Large-Scale Systems*, ed. Lance H. Gunderson and Lowell Pritchard Jr., (Washington: Island Press 2002), 167.
13 Schoennagel et al., "Adapt to more wildfire," 4584.

In another early essay on resilience theory, Holling elaborates on the differences between "engineering resilience" and "ecological resilience."[14] He builds off of O'Neill et al. (1986) and Pimm (1984), arguing that engineering resilience centers on "efficiency, constancy, and predictability" by concentrating on a single state of stability. Engineering resilience is thus measured by a system's ability to resist disturbance and its rate of return to that state after a disturbance.[15] Contrary to engineering resilience, Holling describes ecological resilience as focused on "persistence, change, and unpredictability," with an emphasis on observing influences that could "flip a system into another regime of behavior."[16] Therefore, measuring ecological resilience does not require determining how quickly a system returns to a single state of equilibrium after a disturbance. Rather, it requires determining the "magnitude of disturbance that can be absorbed" before the system's function or purpose changes.[17] Similarly, Pathak and Mahadevia discuss how ecological resilience can be promoted in urban settings through "building safety margins into the design of the system in order to absorb initial shocks, retain functionality, and minimize overall losses."[18] For example, green infrastructure design is often considered resilient because it focuses on reducing and treating urban stormwater at its source while simultaneously providing environmental and social benefits (such as opportunities to attract pollinators through native plants that additionally filter water, as well as for different types of recreation in greenspaces).[19] Holling argues that when managing ecosystems, more attention should be placed on ecological resilience theory rather than on engineering resilience theory because of its ability to augment a system's adaptive capacity.[20] Of note, the National Park Service effectively combines these two notions of resilience and defines it as the "capacity [of a system] to withstand change or recover from unexpected impacts quickly."[21] Resiliency according to the National Park Service would thus be measured by a system's capacity to absorb disturbance as well as its rate of return to stability. These concepts of resilience can additionally be applied to understanding social systems.

Adger defines social resilience as a community's ability to withstand external shocks or stressors, such as political or economic upheaval or natural disasters.[22] As he points out, a social system or population builds resilience when it is able to respond to and cope with stress. Carpenter et al. argue that in addition to the ability of a system to withstand external disturbances, social resiliency includes a system's ability to "self-organize" and build capacity for "learning," "experimentation," "discovery," "evolution," and "innovation."[23] The idea that resilient social systems do not just react well to shocks or stressors, but also have the capacity to proactively learn and evolve from them, may be especially useful when planning for resiliency. Anderies et al. additionally write about social resilience using the term "robustness," which they define as a system's ability to maintain desired characteristics despite changes in its environment or individual elements.[24] Two organizations that illustrate this notion of social resiliency are the United Nations and the Alliance for National and Community Resilience, which both work towards promoting community resilience after natural disasters by returning community members to jobs, re-opening businesses quickly, and ensuring the use of basic services that are needed to keep the economy functioning.[25] Another example of an organization that builds resiliency grounded in this notion is 100 Resilient Cities, a non-profit that leads resiliency efforts through urban and

14 C.S. Holling, "Engineering Resilience versus Ecological Resilience," in *Foundations of Ecological Resilience*, ed. Lance H. Gunderson, Craig R. Allen and C.S. Holling, (Washington: Island Press 2010), 51-66;
15 C.S. Holling, "Engineering Resilience versus Ecological Resilience," 51-66; O'Neill, Robert V., et al., *A Hierarchical Concept of Ecosystems: Monographs in Population Biology, Volume 23.,* (Princeton, NJ: Princeton University Press 1986); Stuart L. Pimm, "The Complexity and Stability of Ecosystems," *Nature* 307, no. 5949 (January 1984): 321-6, doi: 0.1038/307321a0.
16 C.S. Holling, "Engineering Resilience versus Ecological Resilience," 53.
17 C.S. Holling, "Engineering Resilience versus Ecological Resilience," 53-4.
18 Pathak and Mahadevia, "Urban Informality."
19 "What is Green Infrastructure?" Environmental Protection Agency, last modified May 29, 2019, https://www.epa.gov/green-infrastructure/what-green-infrastructure.
20 C.S. Holling, "Engineering Resilience versus Ecological Resilience."
21 Chris Beagan and Susan Dolan, "Integrating Components of Resilient Systems into Cultural Landscape Management Practices," *Change Over Time* 5, no. 2 (Fall 2015): 180-199, https://www.nps.gov/subjects/culturallandscapes/resilientsystems_management.html.
22 W. Neil Adger, "Social and Ecological Resilience: Are They Related?" *Progress in Human Geography* 24, no. 3 (2000): 347-64, https://doi.org/10.1191/030913200701540465; Lindsey K. Campbell et al., "A Social Assessment of Urban Parkland: Analyzing Park Use and Meaning to Inform Management and Resilience Planning," *Environmental Science and Policy* 62 (2016): 34-44, http://dx.doi.org/10.1016/j.envsci.2016.01.014.
23 Steve Carpenter et al., "From Metaphor to Measurement: Resilience of What to What?" *Ecosystems* 4 (2001): 765-81, https://doi.org/10.1007/s10021-001-0045-9
24 John M. Anderies, Marco A. Janssen, and Elinor Ostrom, "A Framework to Analyze the Robustness of Socio-ecological Systems from an Institutional Perspective," *Ecology and Society* 9, no. 1 (2004).
25 Richardson, "What Community Resilience is all About."

community planning and design.[26] Folke, however, argues that the idea of robustness does not capture social-ecological resilience, the idea that social and ecological systems are highly intertwined and are significantly impacted by one another.[27]

When putting resilience theory into practice, it is also imperative to understand the difference between specified and general resilience. When considering specified resilience, planners ought to interpret how specific aspects of a system relate to specific disturbances.[28] This concept is often thought of in relation to the question, "resilience of what, to what?"[29] For example, specified resilience after a wildfire might be developed if a community is able to rebuild damaged structures in similar locations, or if the fire characteristics are within a historical range of variability and the forest is able to regenerate without shifting into a different state.[30] Specified resilience is often used to guide management decisions focused on a particular disturbance or on conserving a specific landscape or species. However, lending too much focus to specified resilience without considering the system as a whole can be risky. In some cases, focusing on building resilience in a select few areas may cause other areas of the system to become less resilient.[31] This is because a key principle of planning for general resilience is understanding that all elements in a system are inherently linked and do not operate in isolation of one another. In this way, general resilience planning is more holistic than specified resilience planning. Further synthesized, general resilience focuses on planning for uncertainty and a whole system's ability to respond to unidentified shocks or stressors.[32] According to Folke et al., general resilience is intentionally vague, and does not specify either "the part of the system that might cross a threshold, or the kinds of shocks the system has to endure."[33] As weather patterns and social-ecological disturbances become more unpredictable, general resilience will become a powerful principle for guiding land management decisions.[34] By strengthening features that confer resilience to an entire system rather than just pieces of it, that system may be able to maintain its core function after an unexpected disturbance.

Another important theoretical concept found in the literature on resilience theory is transformability. Transformability is a fairly radical concept in that it refers to a system's capacity to change states in response to significantly altered conditions and disturbances that lead to widespread systemic shifts.[35] It is important to consider when system conditions become significantly different from historic conditions, or when planning for significantly long periods of time (such as a century).[36] Transformability requires planners and land managers to accept that due to major external condition changes, shocks, and stressors, a system may no longer serve a perceived function, which would require adapting management strategies to serve the changed system; letting the system "return to a desirable state by itself," or, perhaps most challenging, attempting to restore the system back to its desirable state.[37]

26 "What is Urban Resilience?" 100 Resilient Cities, 2019, http://100resilientcities.org/resources/#section-1.
27 Carl Folke, "Resilience: The Emergency of a Perspective for Social-Ecological Systems Analyses," *Global Environmental Change* 16, no. 3 (August 2006): 256-67, https://doi.org/10.1016/j.gloenvcha.2006.04.002.
28 Tania Schoennagel, et al., "Adapt to more wildfire in western North American forests as climate changes," *Proceedings of the National Academy of Sciences*, *114,* no. 18, (2007): 4582–4590, https://doi.org/10.1073/pnas.1617464114.
29 Carl Folke, et al., "Resilience Thinking: Integrating Resilience, Adaptability and Transformability," *Ecology and Society* 15, no. 4 (2010), https://doi.org/10.5751/ES-03610-150420.
30 Schoennagel et al., "Adapt to more wildfire," 4584.
31 Folke et al., "Resilience Thinking."; Schoennagel et al., "Adapt to more wildfire."
32 Schoennagel et al., "Adapt to more wildfire," 4584.
33 Folke et al., "Resilience Thinking."
34 Folke et al., "Resilience Thinking."; Schoennagel et al., "Adapt to more wildfire."
35 Folke et al., "Resilience Thinking."; Schoennagel et al., "Adapt to more wildfire," 4585.
36 Schoennagel et al., "Adapt to more wildfire," 4585.
37 Gunderson et al, "Resilience of Large Scale Resource Systems," 264.

II. Features of Resilience

Gunderson et al. in the essay, "Resilience of Large-Scale Resource Systems,"[38] define the following features that confer resilience: diversity across scales, distribution across scales, and replication or redundancy across scales. Diversity in this essay refers to ecological diversity, or a variety of species whose:

> "interactions reinforce one another and dampen disruptions. Such situations may arise due to compensation when a species with an ecological function similar to another species increases in abundance and the other declines or as one species reduces the impact of a disruption on other species."[39]

Although defined here in an ecological context, the principle of diversity can apply to social and built infrastructure resilience as well; by providing a diversity of recreation experiences and facilities that meet the needs of diverse visitors, for example, open space managers can ensure the continuity of visitor support. The National Park Service also defines diversity as a "safeguard against catastrophic loss by allowing a wide range of responses to stress," which is applicable to social, built infrastructure, as well as ecological resilience.[40] Diverse responses to disturbances prohibit a system from relying on just one, potentially inadequate, response to a disturbance, shock, or stressor.

Distribution, often interchanged with the term connectivity, refers to continuous "spatial and temporal patterns in ecosystems"[41] that enable a diversity of organisms to thrive by an uninterrupted availability of resources, such as habitat and food. This concept also applies to social and built infrastructure resilience; landscapes connected by a multimodal transportation system, for example, could be considered resilient as well as the connectivity of a trail network within a park. A different but related concept of resilient spatial patterns is the idea of modularity, which the National Park Service defines as allowing "structurally or functionally distinct parts [of a system] to retain autonomy during a period of stress with easier recovery from loss."[42] This concept is especially useful when considering built infrastructure. Distinct units of infrastructure, including cultural resources such as historic properties, may rebound from a disturbance if they are not closely linked in proximity and therefore not adversely impacted by one another. However, lending too much focus to the concept of modularity risks losing sight of linkages and dynamics of entire systems.

Replication and/or redundancy refers to the ability of a system to operate multiple, similar functions in the case that one fails due to a disturbance, shock, or stressor. This concept is especially applicable to ecological resilience, as diverse species with similar functions ensure that when one species fails to provide its function such as a specific ecosystem service, another may take its place. The idea of replication applies to social resilience as well; in the case that one trail is no longer usable due to wildfire, for example, a similar trail experience may be provided to the visitor elsewhere. Replication or redundancy is also applicable to built infrastructure resilience, as built infrastructure (such as port-a-lets or drinking water facilities) may need back-up, or a fail-safe mechanism, in the case that a component of that system fails.[43]

III. How is resiliency different than sustainability?

Emergency response agencies, non-governmental organizations, cities, and other community planning entities are increasingly interested in the ways that both sustainability and resilience theory can help secure a future with a high quality of life and a resistance to the impacts of increasing environmental threats.[44] Often thought to be synonymous, the terms sustainability and resilience actually refer to different concepts yet are frequently interchanged with one another. Although their meanings are closely connected, it is important to clearly define the two concepts in order to

38 Gunderson et al, "Resilience of Large Scale Resource Systems," 8.
39 Gunderson et al, "Resilience of Large Scale Resource Systems," 9.
40 "Resilient Systems and Cultural Landscape Management," National Park Service, last modified February 27, 2017, https://www.nps.gov/subjects/culturallandscapes/resilientsystems_management.htm.
41 Gunderson et al, "Resilience of Large Scale Resource Systems," 9.
42 "Resilient Systems and Cultural Landscape Management," National Park Service, last modified February 27, 2017, https://www.nps.gov/subjects/culturallandscapes/resilientsystems_management.htm.
43 Gunderson et al, "Resilience of Large Scale Resource Systems," 10.
44 Dayton Marchese et al., "Resilience and Sustainability: Similarities and Differences in Environmental Management Applications," *Science of The Total Environment* 613-4 (2018): 1275–83, https://doi.org/10.1016/j.scitotenv.2017.09.086.

increase their utility in planning methodologies.[45] Both resilience and sustainability refer to the state of a system or feature over time, focusing on the persistence of that system under normal operating conditions and in response to disturbances. Sustainability focuses on improving a stable functioning system, while resilience focuses on coping with change in dynamic systems. Where sustainability aims to allow a system to operate at an equilibrium, resilience looks for ways in which systems can reorganize dynamically yet still retain system-functioning in the face of uncertainty and disruption.

Sustainability is a fairly mainstream planning concept and is focused on increasing the quality of life for both present and future generations, as defined through a triple bottom line with respect to environmental, social, and economic considerations.[46] Sustainability is often indicated as a goal or a measure of system performance, and interprets how a system can be improved so that it continuously operates at equilibrium.[47] That is, sustainability implies continuity; for example, a food system may be sustainable when its resources can be continually replenished without being depleted or without degrading the conditions (e.g., soil health) required for growth.[48] The primary objective of sustainability is to perpetually promote system equilibrium.

On the other hand, resilience considers the responses of whole systems to unexpected, extreme disturbances or shocks as well as persistent stressors (both natural and human-caused).[49] Resilience initiatives tend to focus on a system's ability to adapt to new conditions while still retaining the same function or identity. Within a scientific domain, resilience theory has evolved into an intellectual framework for understanding how complex systems self-organize and change over time. Resilience is a systems-level concept and is distinct from sustainability in that it is not normative (i.e., it does not necessarily include specific performance measures), and can be achieved at one temporal or spatial scale.[50] Furthermore, resilience tends to prioritize processes of systems or features, whereas sustainability prioritizes outcomes of that system.[51]

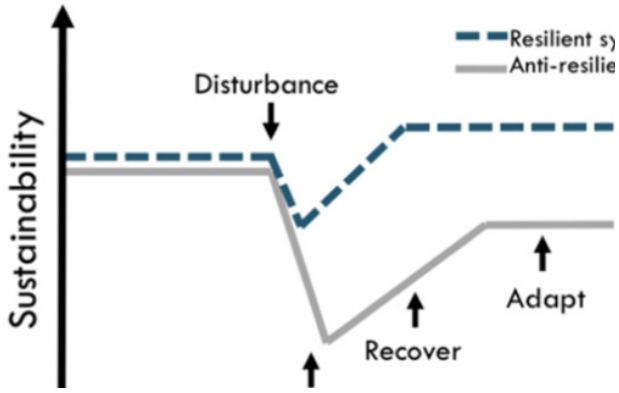


Figure 4: Resilience is an important component of sustainability; systems that are more resilient can better achieve and maintain sustainable operation.

Resilience is an important component of sustainability, and in many cases systems that are more resilient can better achieve and maintain sustainable operation (Fig. 4).[52] Sustainability is insufficient when planning for uncertain and changing conditions. Sustainability is inherently static and presumes there is a point of equilibrium at which one can maintain balance and achieve some level of stability between humanity and the natural world. However, in a world that is inherently dynamic and in disequilibrium, the development of resilient, adaptive systems will be necessary to

45 John M. Anderies et al., "Aligning key concepts for global change policy: robustness, resilience, and sustainability," *Ecology and Society* 18, no. 2 (2013), https://doi.org/10.5751/ES-05178-180208.
46 Marchese et al., "Resilience and Sustainability," 1275–83.
47 Anderies et al., "Aligning key concepts."
48 "*Sustainability vs. Resilience: Why Bouncing Back is the Way of the Future*," Sustainability Degrees, last modified June 20, 2014, https-://www.sustainabilitydegrees.com/blog/sustainability-vs-resilience-why-bouncing-back-is-the-way-of-the-future/.
49 Marchese et al., "Resilience and Sustainability," 1275–83.
50 Anderies et al., "Aligning key concepts."
51Marchese et al., "Resilience and Sustainability," 1275–83.
52 Marchese et al., "Resilience and Sustainability," 1275–83.

achieve sustainability.[53] Resilience does not propose a single, fixed future, but rather, is a dynamic, proactive way of thinking that planners have embraced in order to deal with future uncertainties;[54] it assumes systems are uncertain and there will be unforeseen surprises, such as unexpected outcomes to management schemes.

IV. Brief Exploration of Non-Resilient Land-Use Planning Examples

As mentioned earlier, resilience theory has only recently begun to gain popularity in land management planning. Many past management decisions have prioritized short-term results and, in the process, have neglected or decreased overall resiliency. One notable example of such a management decision is the United States Forest Service's (USFS) practice of fire suppression during most of the twentieth century. After a series of large wildfires known as the "Big Blowup" spread across the western United States in 1910, killing large numbers of firefighters and causing serious damage to towns and forest ecosystems, the USFS decided to manage their land using extreme fire suppression techniques. Any wildfires that started on USFS land were put out as quickly as possible, including natural fires from lightning strikes which are a necessary part of the forest ecosystem.[55] While fire suppression achieved the USFS's short-term goal of reducing loss of life and property, it was not a resilient management decision. Over time fire suppression leads to fuel accumulation and creates conditions for more severe wildfires, which increases risk to surrounding communities and ecosystems. Increases in extreme wildfire frequency create a less diverse ecosystem, reducing the system's ability to respond to shocks or stressors.[56] Natural fire regimes, habitats, and vegetation can be drastically altered with the suppression of fire in an ecosystem. Naturally occurring fires, such as lightning-ignited fires, can help adjust fuel levels in a forested ecosystem by reducing fuel build-up and mitigating impacts from devastating fires. The USFS has since shifted their policies to allow naturally occurring wildfires from lightning-strikes to burn in certain areas of the National Forests. However, years of fire suppression has decreased the resiliency of these forests and has made the restoration of natural fire regimes difficult despite these policy changes.[57]

Rangelands in the U.S. are another example of land that has historically been managed for short-term results rather than long-term ecosystem health and resilience. Especially in arid or semi-arid climates, rangelands are vulnerable to desertification, a land degradation process that reduces the "physical, chemical, and biological potential" of the land and threatens biodiversity and human communities due to decreased yield.[58] When managing for maximum sustained yield without regard for rangeland resilience, multiple practices can lead to desertification, including exploitation of fragile soils, failing to properly replenish soil nutrients, overgrazing shrubs or grasses, and diverting rivers and streams for irrigation. Desertification ultimately causes an ecosystem to shift from one state to a completely different, less productive system. The physical, chemical, and biological components of the system break down and create a feedback loop where the system continues to degrade in a "process of self-destruction."[59] In turn, land degradation can exacerbate drought and other climate-related environmental conditions. Despite initial agricultural successes from short-term yields, the ecosystem becomes unable to respond to desertification, which can cause ramifications to the broader social-ecological system such as species migration, decreased carbon capture from shrubs and grasses, economic crisis, and other breakdowns within a community.[60] Where some historical land-use planning fails to look at the larger picture, resiliency-focused land-use planning looks at how the resiliency of one system can enhance the resiliency of another.

53 Jamais Cascio, "The Next Big Thing: Resilience," *Foreign Policy,* September 28, 2009, https://foreignpolicy.com/2009/09/28/the-next-big-thing-resilience/
54 Andrew Zolli, "Learning to Bounce Back," *New York Times* (New York, NY)*,* November 2, 2012, https://www.nytimes.com/2012/11/03/opinion/forget-sustainability-its-about-resilience.html.
55 "The Great Fire of 1910," United States Forest Service, accessed April 30, 2019, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5444731.pdf.
56 Michelle M. Steen-Adams, et al., "Historical Perspective on the Influence of Wildfire Policy, Law, and Informal Institutions on Management and Forest Resilience in a Multiownership, Frequent-fire, Coupled Human and Natural System in Oregon, USA," *Ecology and Society* 22, no. 3 (2017), http://www.jstor.org/stable/26270161.
57 Carol Miller, "The Hidden Consequences of Fire Suppression," *Park Science* 28, no. 3 (2011-2012), https://www.fs.fed.us/rm/pubs_other/rmrs_2012_miller_c001.pdf.n.
58 "Sustainable Development of Drylands and Combating Desertification: Definition and General Approach to the Problem," Food and Agriculture Organization of the United Nations, 1993, http://www.fao.org/3/v0265e/v0265e01.html.
59 Food and Agriculture Organization, "Sustainable Development of Drylands."
60 Food and Agriculture Organization, "Sustainable Development of Drylands."

V. Applied Resiliency Case Studies

Case Study in Ecological Resilience: Ningaloo Marine Park[61]

As described earlier, understanding principles of systems and resilience theories is incredibly important when working to conserve sensitive ecological areas. Researchers at Ningaloo Marine Park in Australia recognized this and

determined that when certain Marine Protected Areas (MPAs) are conserved based on specific resilience features (such as structural complexity and depth of water) the overall ecological resiliency of marine parks increases, enabling the benthic zone to recover from and mitigate the impacts of temperature disturbances in the ocean. These researchers utilized existing data to identify resilience features of Ningaloo Marine Park, and then incorporated those features into conservation planning. This allowed the researchers to assess current representation of benthic habitats in marine park zones; to identify additional areas of resilience to be included in no-take zones; and to examine the need to refine existing no-take zones.

The researchers assigned resilience features to no-take zones in Ningaloo Marine Park by using a spatial analysis tool that additionally allowed them to assign a level of resilience to a particular area given specific criteria (Table 5). They also tested the correlation between resilience features which enabled "the resilience index to be simplified" with strong resilience features acting as surrogates for other features, however this test also "increased the irreplaceability of the planning units which contained" multiple features.[62] Another layer that the researchers included in their spatial analysis was a socio-economic cost layer, i.e., the social impact of limiting take in a particular zone. Furthermore, the researchers highlighted that their identified no-take zones were not based purely on the ecological resilience index; stakeholder engagement was also crucial in helping to determine no-take zones with low socio-economic cost.

Table 5: Resilience value index used by Ningaloo Marine Park.

		Resilience value		
Resilience feature	**Priority for Ningaloo Reef**	**High (1)**	**Moderate (2)**	**Low (3)**
Depth	Areas deeper than 8 m [19,39]	>8 m	6–8m	<6 m
Structural complexity	Structurally complex areas with high rugosity values [19]	Rugosity value 4–5	Rugosity value 2–3	Rugosity value 0–1
Water mixing	Reef pass areas with high mixing [15]	Reef pass present	N/A	No reef pass present
Macro-algal cover	Areas with low macro-algal cover [13]	Sparse macro-algal cover (<35%)	Patchy macro-algal cover (35–65%)	Dominant macro-algal cover (>65%)
Live coral cover	Areas with high live coral cover [16,39]	Continuous coral(>65%)	Patchy coral(35–65%)	Sparse coral(<35%)
Proximity to human activities	Areas furthest from human activity nodes [10,39]	Low human activity	Moderate human activity	High human activity

Additionally, this study highlighted the importance that incremental conservation design holds for adaptive management. By iteratively evaluating and assigning resilience features to MPAs, identifying no-take zones for conservation can continue to be refined, enabling "critical resilience for climate change induced disturbance."[63] Furthermore, by integrating resilience features and a socio-economic layer into spatial analysis, conservation planners can identify which areas of greatest conservation need also have the least socio-economic cost. Lastly, because it is difficult to predict the effects of climate change, it is imperative that resilience be incorporated into MPAs so that recovery from disturbances is enhanced for upstream as well as downstream areas - a concept with high applicability to open space.

61 Harriet N. Davies et al., "Integrating Climate Change Resilience Features into the Incremental Refinement of an Existing Marine Park," *PLoS ONE* 11, no. 8 (2016): 1-21, doi:10.1371/journal.pone.0161094.
62 Davies et al., "Integrating Climate Change Resilience Features," 6-7.
63 Davies et al., "Integrating Climate Change Resilience Features," 14.

Case Study in Built Infrastructure Resilience: Reconstruction of US 34 - Big Thompson Canyon

Resilience planning is not just for ecologists and community planners; many engineers have recognized the value of incorporating resilience principles into their designs. In 2013, heavy flooding caused significant loss of life and damage to buildings, bridges, and roads along Colorado's Front Range. After these 2013 floods destroyed roads along US 34 - Big Thompson Canyon, the Colorado Department of Transportation (CDOT) and Muller Engineering Company Inc., a civil engineering firm based in Lakewood, Colorado, collaboratively rebuilt a more resilient road system. This construction effort aimed to mitigate future flooding risks in the Big Thompson Canyon by utilizing a custom-designed Resilience Index and a Planning and Environmental Linkage (PEL).

Flood records from 1974 and 2013 show that damage experienced from both events occurred in the same segments of US 34.[64] Thus, the project focused on segments of US 34 that connect Loveland, Colorado to Estes Park, Colorado. This highly traveled road is necessary not only for the tourism industry surrounding Rocky Mountain National Park, but also for the local communities that depend on the road for day-to-day transportation. This project was also guided by PEL, which is an approach to transportation planning that requires decision-makers to consider community, environmental, and economic goals throughout the entire planning and construction process.[65] Colorado's Department of Natural Resources helped the CDOT to predict future shocks and stressors in the US 34 - Big Thompson corridor, including flooding and natural erosion. In doing so, they found that the likelihood of similar flood events occurring at the same road segments in the future was high; that the people who use these roads were vulnerable to future flood disturbances; and that the consequences of similar flood events occurring included both costly reconstruction and potentially loss of life.

Therefore, the CDOT and Muller Engineering's main project goal was to redesign the road in order to mitigate risk in the case of another major flood event. Ultimately, the road was redesigned further away from the riverbed, and bridges and abutments were better designed to handle major flood events. These improvements were identified through a customized resilience scorecard that indicated they would lower the risk of total road destruction in the event of a major flood, averting costly reconstruction and enabling road connectivity for emergency services during a flood. While expensive upfront, these improvements will reduce long-term maintenance costs and will make repairs from future flood damage easier and less expensive. It is expected that these reconstructed segments of the highway should be able to withstand a flood similar to the ones that occurred in 1974 and 2013 with a lower level of rebuilding necessary to make it safe for the public to utilize.

Case Study in Social-Ecological Resilience: Jamaica Bay[66]

An example of shifting planning strategies to be more holistic and interdisciplinary is a pilot project conducted by the USFS in Jamaica Bay, New York City. While the first two examples mentioned above certainly touch on multiple aspects of resilience, they primarily focus on ecology and build infrastructure, respectively. This case study demonstrates the intersection between social and ecological resilience.

Understanding that urban green space has "crucial biophysical buffering capacities,"[67] the USFS wanted to uncover how these biophysical buffer zones could become multi-functional, thereby enhancing the resiliency of Jamaica Bay's waterfront communities in the wake of significant damage caused by Hurricane Sandy. The USFS uncovered that beyond their crucial ecosystem services, urban green space also provides "cultural ecosystem services" by creating opportunities for the public to engage in recreation, build community, and develop a connection to a place or shared resource - ultimately bolstering social-ecological resilience. This study concludes that overall, "parks, through their use by and interactions with humans, are producing vital cultural ecosystem services that may help to strengthen social resilience."[68] This key finding illustrates the significance that green space holds in building the capacity of a

64 Jensen, Randy, and Lizzie Kemp, "Resilient Colorado," Lecture, June 8, 2017, https://www.codot.gov/programs/environmental/transportation-environmental-resources-council-terc/terc-presentation-6-8-17.
65 Daniel J. Marcucci and Lauren M. Jordan, "Benefits and Challenges of Linking Green Infrastructure and Highway Planning in the United States," *Environmental Management* 51, no. 1 (2012): 182-97, doi:10.1007/s00267-012-9966-7.
66 Campbell et al., "A Social Assessment of Urban Parkland," 34-44.
67 Campbell et al., "A Social Assessment of Urban Parkland," 34-44.
68 Campbell et al., "A Social Assessment of Urban Parkland," 34.

community to respond to shocks or stressors, as well as the ability of a community to rebound from a shock. The capability of green space to foster "social cohesion"[69] through diverse and perpetually changing values is pertinent for enabling community strength post-shock, as well as for enabling the stewardship ethic required for building the resiliency of both the community and the ecosystem.

By integrating social and qualitative research methodologies into resiliency planning, planners can better understand the connections between social-ecological resilience and how to enhance both, so that the two systems are mutually reinforcing. In the case of Jamaica Bay, understanding social values was integral to rehabilitating the resiliency of both green space and its neighboring communities post-Hurricane Sandy. This study realized that parks should no longer be considered as "static repositories of services," and instead be understood as "human-produced cultural landscapes where people are co-creators of services in their roles as users, stewards, and ecosystem engineers."[70] To understand this finding is to understand how inseparable social resilience is from ecological resilience; the two must always be considered in tandem when planning for resiliency, as they are often mutually reinforcing.

Case Study at the Intersection of Social, Ecological, and Built Infrastructure Resilience: Resilient Boston Harbor

This case study explores an initiative that seeks to maximize social, ecological, and built infrastructure resilience. The official elevation of the city of Boston, Massachusetts, measured at Logan International Airport, is nineteen feet above sea level. Many places in the city sit even lower than this, and much of the city is vulnerable to flooding and rising sea levels. The sea level around Boston has risen eight inches since 1950. However, sea level rise has accelerated, and the sea around Boston is now rising about one inch every eight years. This sea level rise is mainly due to melting ice caps and changes in ocean circulation. The changes in ocean circulation make Massachusetts especially vulnerable to sea level rise because they increase the frequency and intensity of Nor'easters, winter storms that push water to the coast and cause high tides up to two feet higher than average.[71] Boston, in particular, is vulnerable because of its densely populated waterfront; economic and cultural reliance on the coast; and most of the wetlands surrounding the Shawmut Peninsula, which historically provided natural flood protection, were filled during the 19th century to create more neighborhoods.[72]

In order to prepare for sea level rise and increased floods due to changing storm patterns, the city of Boston developed a long-term vision and comprehensive strategies to increase the resilience of the city's coastline. This vision features neighborhood-specific strategies to invest in Boston's waterfront and protect homes, jobs, infrastructure, and open space against rising sea levels and flood events. Some of the strategies featured in the plan include flood-resilient buildings, elevated landscapes, more waterfront parks, and increased public transportation and access to the waterfront.[73] Boston Mayor Martin J. Walsh sees this as an "opportunity to protect Boston, connect Boston, and enhance Boston, now and for the future."[74] Overall, city government and Boston residents recognize the importance of developing the city's adaptive capacity to respond to rising sea levels and increased flooding. Mayor Walsh referred to this vision as a "new era in [the] Harbor's history," and states that "Boston can show the world that resilience is not only the ability to survive adversity, but to emerge even stronger than before."[75] Working at the nexus of social, ecological, and built infrastructure opportunities ensures that Boston's vulnerability to rising sea levels is being addressed on a systematic level, rather than on an individual project level, and will likely lead to a more comprehensive and effective response to future shocks and stressors.

69 Campbell et al., "A Social Assessment of Urban Parkland," 34.
70 Campbell et al., "A Social Assessment of Urban Parkland," 42.
71 "Massachusetts," States, SeaLevelRise.Org, accessed August 21, 2019, https://sealevelrise.org/states/massachusetts/.
72 Betsy Mason, "How Boston Made Itself Bigger," *National Geographic*, June 13, 2017, https://news.nationalgeographic.com/2017/06/Boston-landfill-maps-history/. Tn t
73 "Transformative Plan to Create Resilient, Open Boston Harbor Unveiled," City of Boston Department of Environment, October 17, 2018, https://www.boston.gov/news/transformative-plan-create-resilient-open-boston-harbor-unveiled.
74 City of Boston, "Transformative Plan...Unveiled."
75 City of Boston, "Transformative Plan...Unveiled."

VI. Samples of Relevant Resiliency Plans/Frameworks

Since it was first introduced, the application of resilience theory to natural resource management and social-ecological systems has become increasingly popular. The Resilience Alliance, for example, is an international research organization that brings together interdisciplinary researchers to analyze the dynamics of social-ecological systems.[76] More and more organizations and public entities are now applying resilience theory to natural resource and community planning as well. The Colorado Department of Local Affairs (DOLA) is one organization that has prioritized resiliency planning and continues to inform local-level plans statewide. These Colorado-based plans served as the inspiration and guidance for this Framework. The purpose, background, and how these frameworks inspired the Jefferson County Open Space Resiliency Framework are illustrated below.

The Colorado State Resiliency Framework (CRF)[77]

A. Background

The main guide for creating resiliency plans in Colorado comes from the Colorado Resiliency Office (CRO), which was created in the wake of several environmental disasters in 2012 and 2013. During these years, flooding and wildfires took seventeen lives and destroyed 3,000 homes, which required extensive cleanup and rebuilding of necessary infrastructure within the state. Since weather events are likely to increase in severity and frequency now and in the future, Colorado took action to encourage the state to build infrastructure that could withstand large-scale change. To do this, the state of Colorado created the CRO within the DOLA. The CRO then developed a statewide resiliency framework to encourage local municipalities to adopt more resilient building, social, and ecological management practices to mitigate the impacts of future weather events, climate change, and other socioeconomic disturbances.[78, 79]

B. Purpose

The main purpose of the Colorado Resiliency Framework is to build the capacity for proactive management in the state of Colorado, as opposed to encouraging reactive management. This idea is captured in the definition of resiliency established by the state. According to the CRF, resiliency is:

> "the ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges - including disasters and climate change - and maintain quality of life, healthy growth, durable systems, and conservation of resources for present and future generations."[80]

Recognizing that achieving general resilience is a lofty goal, the CRF breaks resiliency into six different sectors in order to make resilience more achievable, although the CRO also acknowledges that these sectors cannot be thought of in complete isolation from one another. These sectors are economic, community, health and social, housing, watersheds and natural resources, and infrastructure resilience.[81] In addition to defining resilience, the CRF lays out five goals to increase resiliency within the state:

1. Reduce risk of environmental hazards for communities.
2. Enhance resiliency planning knowledge and engineering across the state.
3. Ensure that policies align with and enhance resiliency.
4. Establish social norms of resiliency within communities and individuals.
5. Invest in resiliency across the state.[82]

76 "About," Resilience Alliance, accessed April 29, 2019, https://www.resalliance.org/about.
77 "Colorado Resiliency Framework," Colorado Department of Local Affairs, May 28, 2015.
78 "Colorado's Resiliency Story," Colorado Department of Local Affairs, https://www.coresiliency.com/storymap.
79 Marcus Lindner et al., "Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems," *Forest ecology and management* 259, no. 4 (2010): 698-709.
80 "Colorado Resiliency Framework," 10.
81 "Colorado Resiliency Framework," 35.
82 "Colorado Resiliency Framework," 35.

Overall, the CRF paints a vision of what a future Colorado could look like despite changing conditions. Although the CRF remains broad to account for the myriad of climates, shocks, stressors, and uses of resources statewide, it establishes a means to start thinking about and planning for resiliency statewide.

C. Influence on the JCOS Resiliency Framework

The CRF's goal is to inspire and inform plans at the county/municipal level, thus much of its content informed the Framework work by the following:

- ◊ *Definition of Resiliency:* The statewide definition of resiliency illustrated in the CRF applies to JCOS. Following the definition laid out in the state plan also helps maintain a level of consistency with statewide and neighboring community management decisions.
- ◊ *Content:* Definitions for elements such as shocks and stressors from the CRF informed this Framework.

The Larimer Community Resiliency Framework (LCRF)[83]

A. Background

Larimer County is located in the north-central Front Range of Colorado and encompasses both the mountains in the west and flat agricultural land in the east. It is the sixth largest county in Colorado by population, and population growth is increasing at a rapid rate statewide. Like most Front Range communities, Larimer County has been subjected to both severe fire and flood events in recent years. The High Park Fire (June 2012), which affected 87,200 acres and destroyed 259 homes, was the largest, most destructive fire in the history of Larimer County. The following year, Larimer County was hit with major floods (September 2013), which severely damaged homes, commercial buildings, and roads (which isolated many mountain communities for extended periods of time and cut off access to Rocky Mountain National Park via highway US 34). Larimer County will likely continue to experience other shocks and stressors like these in the future, and to better prepare for events such as these, the county has developed a resiliency framework.

The LCRF, drafted in 2016, was based on the CRF. Resiliency in Larimer County communities is directly impacted by social, economic, physical, and institutional factors. Existing conditions of Larimer County were identified as they pertain to each of the six sectors as described in the CRF (community, economic, health and social, housing, infrastructure, and watersheds and natural resources resilience) and analyzed based on their strengths and challenges in order to establish baseline conditions, identify gaps, and create a roadmap for what the county envisions for the future.

B. Purpose

The vision for the LCRF is to create a connected, collaborative, and cooperative region that proactively works together to strengthen systems, resolve complex issues, and chart a path toward a resilient future in which Larimer County's vulnerability to adverse changes and potential disasters is reduced. The LCRF lays out eight specific goals for achieving this:

1. Develop regional, long-range, comprehensive planning that is adaptive and collaborative.
2. Foster awareness, preparedness, self-sufficiency, and a greater sense of community by engaging and educating residents of the county.
3. Increase energy and resource efficiency and reduce risk appropriate to rural and urban contexts by developing and implementing appropriate construction standards.
4. Increase the range of housing options and increase the stock of affordable housing through traditional means as well as creative land use, building codes, and measures for innovative housing.
5. Develop and fund a regional, multi-modal transportation network using public and private partnerships at all levels.

83 "The Larimer Community Resiliency Framework," Larimer County, February 2016.

6. Manage natural resources through adaptive planning and management of land use, especially watersheds, floodplains, agricultural land, and the Wildland-Urban Interface.
7. Build public/private/non-profit sector partnerships to support and achieve the community's vision and goals.
8. Support the diverse production and supply needs of a sustainable supply chain for the regional food system.[84]

The LCRF also lays out a specific strategy for each resiliency sector identified in the CRF. These strategies define the objectives of various resiliency projects in the county and describe distinct plans of action that will be undertaken in an effort to achieve the CRF's goals (Fig. 5).

C. Influence on the JCOS Resiliency Framework

The LRCF informed the Framework by the following:

- ◊ *Scale:* This is an example of a plan developed on a county level and therefore provided a perspective that was not found in the CRF. Additionally, there are many similarities between Larimer and Jefferson Counties, since they are both Front Range communities and face similar management challenges, especially ecological shocks and stressors.
- ◊ *Vision of Resiliency:* The LCRF establishes objectives and guiding principles for achieving resiliency within the county, which was modeled in this Framework. The inclusion of "what the framework is not" and the way the LCRF placed boundaries on the scope of the project which also influenced the structure of this Framework.
- ◊ *Layout and Formatting:* This plan flows well, and much of this Framework's organization is modeled after the LCRF.
- ◊ *Graphics and Tables:* The information presented via graphics and tables within the LCRF are easily digestible, and much of the graphic design within this Framework was modeled after the LCRF.

City of Boulder Resilience Strategy[85]

A. Background

The City of Boulder, known for its progressive policies, protection of open space, and climate action plans, became one of the first 32 cities chosen to participate in 100 Resilient Cities, an initiative run by the Rockefeller Foundation to encourage more cities to develop resiliency strategies.[86] Before creating their own framework, the City of Boulder was asked by the CRO to help facilitate creating the vision and strategies for a statewide plan. Before the completion of the statewide plan in 2015, the City of Boulder began creating its own strategy for resilience which was completed in 2016.[87]

In this plan, the City of Boulder defines resiliency as "the ability of a community to prepare for and respond effectively to shocks and stressors."[88] While this definition is not as specific as the one found in the CRF, it does acknowledge that "the future isn't static," which other relevant plans do not illustrate as clearly.[89]

B. Purpose

The City of Boulder Resilience Strategy (the Strategy) establishes a framework to empower the City of Boulder's community to positively respond to natural disasters and changing climate conditions, and evolve with other changing environmental, social, and infrastructural conditions. The Strategy is guided by three approaches: "connect and prepare," "partner and innovate," and "transform and integrate."[90] The "connect and prepare" approach aims to

84 "The Larimer Community Resiliency Framework," 57-58.
85 "City of Boulder Resilience Strategy," The City of Boulder, 2017.
86 "About Us," 100 Resilient Cities.
87 "City of Boulder Resilience Strategy," 52.
88 "City of Boulder Resilience Strategy," 18.
89 "Resilience," The City of Boulder, accessed March 14, 2019, https://bouldercolorado.gov/resilience.
90 "City of Boulder Resilience Strategy," 24.

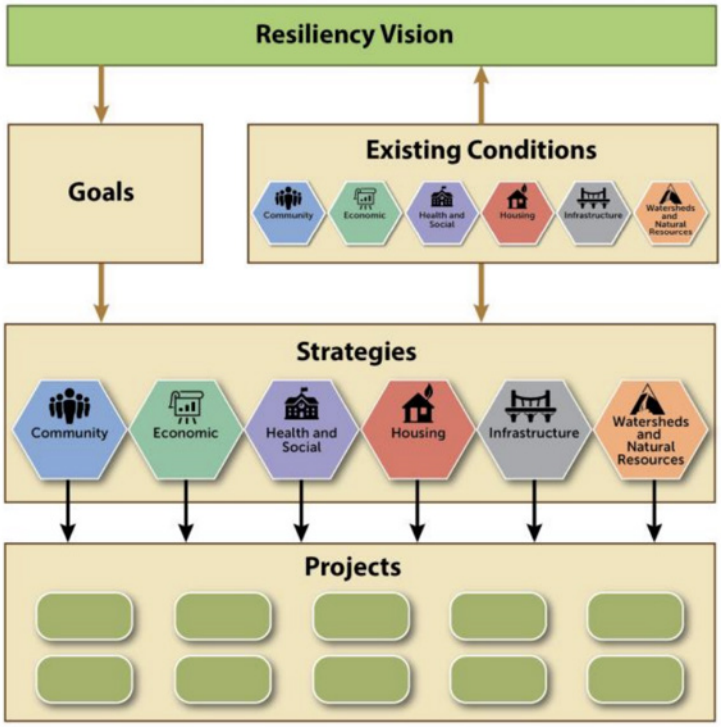


Figure 5: Larimer County's roadmap to resiliency. Larimer County identified existing conditions, goals, and strategies through a multi-step process that combined technical analysis with robust community engagement. Multiple projects under each resiliency sector have been proposed in the framework.

strengthen community connections and the ability for community members to proactively prepare for future shocks and stressors. The "partner and innovate" approach aims to leverage relevant research being conducted by a wide variety of community members such as federal organizations, the university, and citizen scientists. This approach also aims to crowdsource pertinent information and data, so that the City of Boulder can understand and proactively address emerging challenges. The "transform and integrate" approach aims to embed resilience values into citywide systems so that the city is not locked into a single pathway that disallows flexibility and adaptability.

Similar to other resiliency frameworks that take a community-centered approach to planning, the Strategy divides resiliency approaches into four main categories: leadership and strategy, health and wellbeing, economy and society, and infrastructure and environment.[91] The plan works to engage the entire community through education, policies, and communication practices. The City of Boulder additionally establishes robust means for community members to constantly engage with the planning process and to influence standards, expectations, and visions. These interactions will also enable constant avenues for plan evolution, as well as establish actionable strategies for achieving resiliency.

C. Influence on the JCOS Resiliency Framework

The Strategy informed the Framework by the following:

- ◊ *Vision of Resiliency:* The Strategy sets up a clear vision of resiliency that inspired the addition of a "vision of resiliency" for JCOS at the beginning of this document.
- ◊ *Layout and Formatting:* This Framework took inspiration from the simplicity and graphic-forward layout of the Strategy.
- ◊ *Content:* The document's ability to synthesize complex topics related to systems-change and resiliency, and the way it highlights bright spots and opportunities, was influential to the JCOS Framework.
- ◊ *Executive Summary:* The inclusion of a concise and graphic-heavy executive summary that explains the purpose of the Strategy informed this Framework.

91 "City of Boulder Resilience Strategy," 19.

VII. Conclusion

Resiliency in land planning enables systems to adapt to new or changing conditions. The literature identifies three types of resiliency: ecological, social, and engineering resiliency. Engineering resiliency as Holling describes it is a measure of how quickly a system can return to a stable equilibrium and has fallen somewhat out of fashion in favor of the more dynamic and adaptive concept of ecological resiliency. Most of the literature on social resiliency discusses

social and ecological resiliency as one entity: socio- or social-ecological resilience. As the sample case studies in this literature review note, the concepts of social and ecological resilience are highly entwined not only in theory but also in practice. Built infrastructure, social, and ecological systems are dynamic and nested, and by attempting to categorize forms of resilience, project planners can miss out on the interconnections between and within systems.

A gap in the literature regarding resilience planning implementation is a lack of specific examples of metrics and indicators of success. For example, very little guidance is given in the outlined resiliency frameworks on how to measure levels of resiliency quantitatively and qualitatively. The Ningaloo Marine Park case study does provide a good example of an ecological resilience index based on identified resilience features, yet this index is heavily focused on ecological features and does not fully account for social and built infrastructure resilience features. Furthermore, early measures of resilience (i.e., Holling), are mathematically complicated, lending little applicability to modern resilience metrics in varying contexts. There appears to be a lack of resilience indices that are easily accessible for land managers who are not trained systems-thinkers or academics.

Reviewing the CRF and other Colorado-based resiliency frameworks was necessary for understanding the existing landscape of resilience planning efforts statewide. This Framework needs to relate to and remain relatively consistent with other planning efforts statewide, especially the CRF. However, this Framework is unique in that it is open space management-specific and does not encompass resiliency strategies for the broader Jefferson County community. Therefore, this Framework can fill a gap in resilience planning and serve as a model for other open space organizations to create similar documents.

APPENDIX F: SOURCES

"About Us." 100 Resilient Cities. Last modified 2019. http://www.100resilientcities.org/about-us/.

"About Us." BoCo Strong. January 2015. http://bocostrong.org/community-powered-resilience/.

"About Us." Jefferson County Colorado Open Space. Accessed March, 2019. https://www.jeffco.us/1571/About-Us.

"About." Resilience Alliance. Accessed April 29, 2019. https://www.resalliance.org/about.

"Adaptability in Resilient Systems." National Park Service. Last modified February 24, 2017. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_adaptability.htm.

"Case Studies: Profiles of Resilience in Action." Colorado Resilience Resource Center. Accessed March 19, 2019. https://www.coresiliency.com/case-studies.

"City of Boulder Resilience Strategy." The City of Boulder. 2017.

"Colorado Resiliency Framework." Colorado Department of Local Affairs. May 28, 2015.

"Colorado's Resiliency Story." Colorado Department of Local Affairs. Accessed March 10, 2019. https://www.coresiliency.com/storymap.

"Conservation Greenprint." Jefferson County Open Space. Accessed August 21, 2019. https://www.jeffco.us/DocumentCenter/View/12971/Jeffco-Open-Space-Conservation-Greenprint?bidId=

"Diversity in Resilient Systems." National Park Service. Last modified February 24, 2017. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_diversity.htm

"Ecosystems and Their Services." Millennium Assessment. Accessed October 14, 2019. https://www.millenniumassessment.org/documents/document.300.aspx.pdf

"Modularity in Resilient Systems." National Park Service. Last modified February 24, 2017. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_modularity.htm.

"National Disaster Recovery Framework." Federal Emergency Management Agency. September 2011. https://www.fema.gov/pdf/recoveryframework/ndrf.pdf.

"National Park Service Climate Change Response Strategy." National Park Service. Last modified September 2010. https://www.nps.gov/subjects/climatechange/upload/NPS_CCRS-508compliant.pdf.

"Network Connectivity in Resilient Systems." National Park Service. Last modified February 24, 2017. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_network.htm.

"Redundancy in Resilient Systems." National Park Service. Last modified February 24, 2017. /https://www.nps.gov/subjects/culturallandscapes/resilientsystems_redundancy.htm.

"Resilience." The City of Boulder. Accessed March 14, 2019. https://bouldercolorado.gov/resilience.

"Resilient Systems and Cultural Landscape Management." National Park Service. Last modified February 27, 2017. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_management.htm.

"Sustainability vs. Resilience: Why Bouncing Back is the Way of the Future." Sustainability Degrees. Last modified June 20, 2014. https://www.sustainabilitydegrees.com/blog/sustainability-vs-resilience-why-bouncing-back-is-the-way-of-the-future/

"Sustainable Development of Drylands and Combating Desertification: Definition and General Approach to the Problem." Food and Agriculture Organization of the United Nations. 1993. http://www.fao.org/3/v0265e/v0265e01.html.

"The Great Fire of 1910." United States Forest Service. Accessed April 30, 2019. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5444731.pdf.

"The Larimer Community Resiliency Framework." Larimer County. February 2016.

"US 34 Big Thompson Canyon Program Management – Colorado Department of Transportation Region 4." Muller Engineering. Accessed March 20, 2019. https://www.mullereng.com/us-34-big-thompson-canyon-program-management-–-colorado-department-transportation-region-4.

"US 34 BIG THOMPSON CANYON RESILIENCY IMPLEMENTATION MAPBOOK." Colorado Department of Transportation. September 2017. https://www.codot.gov/projects/floodrelatedprojects/us-34-big-thompson-canyon-1/additional-information/resiliency-mapbook.

"What is Green Infrastructure?" Environmental Protection Agency. Last modified May 29, 2019. https://www.epa.gov/green-infrastructure/what-green-infrastructure

"What is Resilience?" The City of Boulder. Last modified 2019. https://bouldercolorado.gov/resilience.

"What is Urban Resilience?" 100 Resilient Cities. Last modified 2019. http://100resilientcities.org/resources/#section-1.

Adger, W. Neil. "Social and Ecological Resilience: Are They Related?" *Progress in Human Geography* 24, no. 3 (2000): 347-64. doi: 10.1191/030913200701540465.

Anderies, John M., Carl Folke, Brian Walker, and Elinor Ostrom. "Aligning Key Concepts for Global Change Policy: Robustness, Resilience, and Sustainability." *Ecology and Society* 18, no. 2 (2013). https://doi.org/10.5751/ES-05178-180208.

Anderies, John M., Marco A. Janssen, and Elinor Ostrom (2004). A Framework to Analyze the Robustness of Socio-ecological Systems from an Institutional Perspective. *Ecology and Society* 9, no. 1.

Beagan, Chris, and Susan Dolan. "Integrating Components of Resilient Systems into Cultural Landscape Management Practices." *Change Over Time* 5, no. 2 (2015): 180-199. https://www.nps.gov/subjects/culturallandscapes/resilientsystems_management.html.

Campbell, Lindsey K., Erika S. Svendsen, Nancy F. Sonti, and Michelle L. Johnson. "A Social Assessment of Urban Parkland: Analyzing Park Use and Meaning to Inform Management and Resilience Planning." *Environmental Science & Policy* 62, (2016): 34-44. http://dx.doi.org/10.1016/j.envsci.2016.01.014.

Carpenter, Steve, Brian Walker, J. Marty Anderies, and Nick Abel. "From Metaphor to Measurement: Resilience of What to What?" *Ecosystems* 4 (2001): 765-81.

Cascio, Jamais. "The Next Big Thing: Resilience." *Foreign Policy.* September 28, 2009. https://foreignpolicy.com/2009/09/28/the-next-big-thing-resilience/.

City of Boston Department of Environment. "Transformative Plan to Create Resilient, Open Boston Harbor Unveiled." October 17, 2018. https://www.boston.gov/news/transformative-plan-create-resilient-open-boston-harbor-unveiled.

Davies, Harriet N., Lynnath E. Beckley, Halina T. Kobryn, Amanda T. Lombard, Ben Radford, and Andrew Heyward. "Integrating Climate Change Resilience Features into the Incremental Refinement of an Existing Marine Park." *PLoS ONE* 11, no. 8 (2016): 1-21. doi:10.1371/journal.pone.0161094.

Folke, Carl, Reinette Biggs, Albert V. Nordström, Belinda Reyers, and Johan Rockström. "Social-ecological resilience and biosphere-based sustainability science." *Ecology and Society* 21, no. 3 (2016). http://dx.doi.org/10.5751/ES-08748-210341.

Folke, Carl. "Resilience: The Emergency of a Perspective for Social-Ecological Systems Analyses." *Global Environmental Change* 16, no. 3 (2006): 256-67. https://doi.org/10.1016/j.gloenvcha.2006.04.002.

Folke, Carl, Stephen R. Carpenter, Brian Walker, Marten Scheffer, Terry Chapin and Johan Rockström. "Resilience Thinking: Integrating Resilience, Adaptability and Transformability." *Ecology and Society* 10, no. 4 (2010). https://doi.org/10.5751/ES-03610-150420.

Fuller, Lauren and Christopher P. Quine. "Resilience and tree health: a basis for implementation in sustainable forest management." *Forestry: An International Journal of Forest Research* 89, no.1 (2016): 7–19. https://doi.org/10.1093/forestry/cpv046.

Gunderson, Lance H. and Craig R. Allen. Introduction to *Foundations of Ecological Resilience, xiii-xxv.* Edited by Lance H. Gunderson, Craig R. Allen and C.S. Holling. Washington: Island Press, 2010.

Gunderson, Lance H., Lowell Pritchard Jr., C.S. Holling, Carl Folke, and Garry D. Peterson. "A Summary and Synthesis of Resilience in Large-Scale Systems." In *Resilience and the Behavior of Large-Scale Systems,* edited by Lance H. Gunderson and Lowell Pritchard Jr., 249-266. Washington: Island Press, 2002.

Gunderson, Lance H., C.S. Holling, Lowell Pritchard Jr., and Garry D. Peterson. "Resilience of Large-Scale Resource Systems." In *Resilience and the Behavior of Large-Scale Systems,* edited by Lance H. Gunderson and Lowell Pritchard Jr., 3-20. Washington: Island Press, 2002.

Gunderson, Lance H. and Carl J. Walters. "Resilience in Wet Landscapes of Southern Florida." In *Resilience and the Behavior of Large-Scale Systems,* edited by Lance H. Gunderson and Lowell Pritchard Jr., 165-182. Washington: Island Press, 2002.

Holling, C.S. "Engineering Resilience versus Ecological Resilience." In *Foundations of Ecological Resilience*, edited by Lance H. Gunderson, Craig R. Allen and C.S. Holling, 51-66. Washington: Island Press, 2010.

Holling, C.S. “Resilience and Stability of Ecological Systems.” In *Foundations of Ecological Resilience*, edited by Lance H. Gunderson, Craig R. Allen and C.S. Holling, 19-49. Washington: Island Press, 2010.

Humphrey, Steven. “Infrastructure Resilience - Highway 34 Big Thompson Canyon, Colorado.” Lecture at Muller Engineering, Lakewood, Colorado. February 8, 2019.

Jensen, Randy, and Lizzie Kemp. “Resilient Colorado.” Lecture. June 8, 2017. https://www.codot.gov/programs/environmental/transportation-environmental-resources-council-terc/terc-presentation-6-8-17.

Lindner, Marcus, Michael Maroschek, Sigrid Netherer, Antoine Kremer, Anna Barbati, Jordi Garcia-Gonzalo, and Rupert Seidl. “Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems.” *Forest ecology and management* 259, no. 4 (2010): 698-709.

Marchese, Dayton, Erin Reynolds, Matthew E. Bates, Heather Morgan, Susan Spierre Clark, and Igor Linkov. “Resilience and Sustainability: Similarities and Differences in Environmental Management Applications.” *Science of The Total Environment* 613–4 (2018): 1275–83. https://doi.org/10.1016/j.scitotenv.2017.09.086.

Marcucci, Daniel J., and Lauren M. Jordan. “Benefits and Challenges of Linking Green Infrastructure and Highway Planning in the United States.” *Environmental Management* 51, no. 1 (2012). 182-97. doi:10.1007/s00267-012-9966-7.

Mason, Betsy. “How Boston Made Itself Bigger.” *National Geographic*, June 13, 2017. https://news.nationalgeographic.com/2017/06/Boston-landfill-maps-history/.

Meadows, Donella H. *Thinking in Systems: A Primer,* edited by Diana Wright. London: Earthscan, 2009.

Miller, Carol. “The Hidden Consequences of Fire Suppression.” *Park Science* 28, no. 3 (2012). https://www.fs.fed.us/rm/pubs_other/rmrs_2012_miller_c001.pdf.n.

Muller Engineering. “US 34 Big Thompson Canyon Program Management – Colorado Department of Transportation Region 4.” Accessed March 2019. https://www.mullereng.com/us-34-big-thompson-canyon-program-management-––colorado-department-transportation-region-4.

O’Neill, Robert V., Donald Lee Deangelis, J.B. Waide, and Timothy F. H. Allen. *A Hierarchical Concept of Ecosystems: Monographs in Population Biology, Volume 23.* Princeton, NJ: Princeton University Press (1986).

Pathak, Minal and Mahadecia Darshini. “Urban Informality and Planning: Challenges to Mainstreaming Resilience in Indian Cities” in *Resilience-Oriented Urban Planning*, edited by Yoshiki Yamagata and Ayyoob Sharifi, 49-66. Springer International Publishing AG (2018).

Pimm, Stuart L. “The Complexity and Stability of Ecosystems.” *Nature* 307, no. 5949 (January 1984). 321-6. doi: 0.1038/307321a0.

Resilience Measurement Technical Working Group. “Measuring Shocks and Stressors as Part of Resilience Measurement.” *Food Security Information Network Technical Series* 5 (2015). http://www.fsincop.net/fileadmin/user_upload/fsin/docs/resources/1_FSIN_TechnicalSeries_5.pdf.

Richardson, Roland. “What Community Resilience is all About.” *National Recreation and Parks Association.* 2016. https://www.nrpa.org/blog/what-community-resilience-is-all-about/

SeaLevelRise.Org. “Massachusetts.” States. Accessed August 21, 2019. https://sealevelrise.org/states/massachusetts/.

Schoennagel, Tania., Jennifer K. Balch., Hannah Brenkert-Smith, Philip E. Dennison, Brian J. Harvey, Meg A. Krawchuk, Nathan Mietkiewicz, et al. Adapt to more wildfire in western North American forests as climate changes. *Proceedings of the National Academy of Sciences*, 114 no. 18 (2017). 4582–4590. https://doi.org/10.1073/pnas.1617464114.

Steen-Adams, Michelle M, Susan Charnley, and Mark D. Adams. “Historical Perspective on the Influence of Wildfire Policy, Law, and Informal Institutions on Management and Forest Resilience in a Multiownership, Frequent-fire, Coupled Human and Natural System in Oregon, USA.” *Ecology and Society* 22, no. 3 (2017). http://www.jstor.org/stable/26270161.

Zolli, Andrew. “Learning to Bounce Back.” *New York Times.* (New York, NY.) November 2, 2012. https://www.nytimes.com/2012/11/03/opinion/forget-sustainability-its-about-resilience.html.