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Economic Decision Guide Software (EDGe$) Case Study:

Droughts in Riverside County, California

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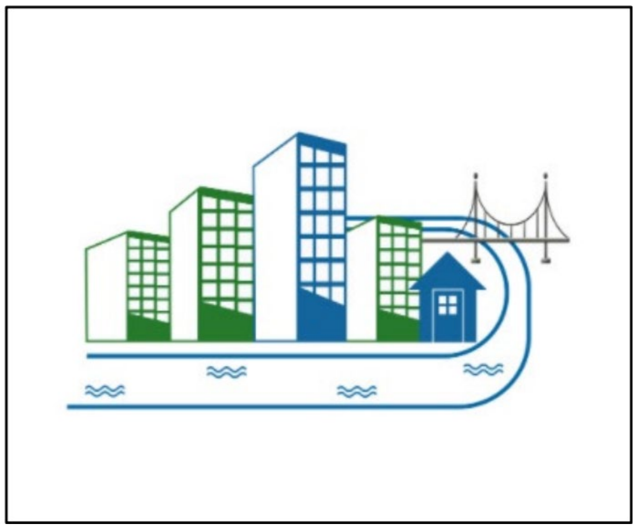

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Abstract

This study uses the Economic Decision Guide Software (EDGe$) Online Tool to evaluate a use case involving three potential drought resilience strategies in Riverside County, California: 1. urban landscape conversion, 2. stormwater capture and reuse, and 3. purple pipe water recycling. The analysis relies on publicly available data to compare the costs, benefits (non-disaster and disaster-related), and externalities of each investment over a 20-year period. Results show that urban landscape conversion provides the highest overall return. These findings highlight the value of accounting for non-disaster benefits and externalities in economic evaluations of resilience projects with a use case addressing slow and persistent stressors based on weather extremes (e.g., drought conditions). The study shows how tools like EDGe$ can support informed decision-making by helping communities compare costs and benefits when planning for drought resilience.

Keywords

Benefit-cost analysis; drought resilience; economic analysis; economic decision tool; externalities; resilience planning; stormwater capture; urban landscape conversion; water recycling.

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1. Introduction

1.1. Economic Decision Guide Software (EDGe$) Online Use Cases

Economic evaluation tools have become increasingly important for communities seeking to make informed decisions about infrastructure investments and resilience planning. The EDGe$ platform is one such tool designed to help with benefit-cost analyses (BCAs) for resilience projects. BCAs help decision-makers compare the expected benefits and costs of an investment (U.S. Department of Transportation, 2025). This type of analysis enables communities to evaluate multiple investment options and identify those that deliver the best returns while addressing their specific needs.

This research takes a case study approach to examine drought resilience planning in Riverside County, California. This is a fictional but realistic case study, using publicly available data to model plausible investment scenarios. While some case studies mainly rely on qualitative data such as interviews and observations (Baxter & Jack, 2008; McCombs, 2023), this analysis is quantitative, focusing on numerical cost and benefit estimates to evaluate resilience strategies.

Riverside County faces water shortages that require strategic planning and investment in drought resilience infrastructure. This study examines three specific mitigation strategies: urban landscape conversion, stormwater capture and reuse infrastructure, and purple pipe water recycling networks. The research question guiding this analysis is: Which drought resilience investment strategy offers the greatest economic net value for Riverside County communities when considering both costs and benefits?

The EDGe$ Online platform facilitates this analysis by being able to compare investment alternatives while accounting for various economic factors including implementation costs and operational expenses. This case study demonstrates how communities can use economic analysis tools to support informed decision-making in resilience planning.

1.2. EDGe$ Online – Select Past Uses

There are six previous examples of EDGe$ being applied across varying cases, both real and hypothetical. Each is briefly described below.

1.2.1. Jackson County Utility Authority, Mississippi

In Jackson County, Mississippi, the local utility authority applied EDGe$ as part of planning efforts to replace three older wastewater treatment plants with a single, consolidated water reclamation facility designed to operate from 2030 to 2080. Because the site was in a flood-prone area and sea level was expected to rise, planners evaluated two protective berm heights – one designed for current 500-year flood levels and another for projected 2080 flood levels. Working with the Program for Local Adaptation to Climate Effects: Sea-Level Rise (PLACE:SLR), the team used EDGe$ to compare costs and benefits over a 50-year period, factoring in both protection for the facility and broader community benefits such as reduced disruptions to households, institutions, and a nearby oil refinery. Results showed both berm options to be cost-effective, and the analysis showed the trade-offs between short-term cost-effectiveness and long-term flood protection (National Institute of Standards and Technology, 2021a).

1.2.2. Biloxi Bay, Mississippi

Along Biloxi Bay, Mississippi, the privately owned Camp Wilkes property faced shoreline erosion after a bulkhead installed in 2016 failed within a few years. The property owners partnered with the Coastal Conservation and Restoration Program to explore replacing the failed bulkhead with a living shoreline. With support from PLACE:SLR, the team used EDGe$ to compare the long-term costs and benefits of living shorelines and bulkheads over a 60-year period. The analysis assumed bulkheads would need replacement every 25 years, while living shorelines would have lower maintenance and replacement costs. Results showed that a living shoreline would be cost-effective even if its initial construction cost was more than triple that of a bulkhead. Further analysis showed it would still be a good investment if a bulkhead needed to be replaced in as little as 15 years, which was well within the owner's 30-year planning horizon. This study also highlighted how EDGe$ can help property owners compare the pros and cons of different methods used to protect shorelines over time and with different project costs (National Institute of Standards and Technology, 2021b).

1.2.3. Hospital Case Study

A hospital case study examined a hypothetical city's decision to relocate its hospital after a 50-year flood rendered it inoperable for a full year, causing $32 million in structural damage and forcing patients to travel an additional 20 kilometers to nearby hospitals. The city used EDGe$ to compare two potential sites – a suburban location with larger floor space versus a downtown location. Results showed that both sites produced nearly equivalent economic outcomes. The suburban site had a net present value of approximately $343.7 million compared to $342.1 million for the downtown site, a difference of about $1.6 million, or less than 0.5% of total net benefits [11].

1.2.4. Levee Case Study

A levee case example analyzed a hypothetical city's flood mitigation strategy following a 100-year flood, comparing two alternatives: buying out all 600 properties in the floodplain to create greenspace or constructing a 1.5-mile levee requiring the purchase of 200 properties. Through the use of the EDGe$ software, each option's costs and benefits were evaluated. The results showed that the buyout option provided greater benefits, with an NPV more than three times that of the levee alternative [12].

1.2.5. Riverbend Case Study

A riverbend case study focused on earthquake preparedness for a small, fictional city of 50 000 people whose four-lane interstate bridge to neighboring Fallsborough was vulnerable to earthquake damage. The planning team used EDGe$ to evaluate two alternatives: retrofitting the existing bridge for $3.5 million versus constructing a new earthquake-resistant bridge for $7.8 million that would also reduce traffic congestion. In the end, the new bridge was found to be a more optimal investment compared to retrofitting the existing bridge [13].

1.2.6. Wildland Urban Interface (WUI) Case Study

The WUI case study evaluated a hypothetical forest management strategy for several towns after a 25-year wildfire burned nearby forests along the river, causing water treatment costs to double due to increased sediment and resulting in $2 million in additional expenses. The EDGe$ Online Tool was used to compare a status quo scenario to an alternative scenario in which a $6.9 million forest management plan – consisting of controlled burns every four years and reseeding certain areas with straw barriers – was implemented. The plan proved to be economically viable with an NPV of approximately $453 000 (National Institute of Standards and Technology, 2017).

1.2.7. Summary

The EDGe$ Tool has shown that it can be applied in many different situations, including hospital relocation and flood mitigation. In each case, the EDGe$ was used to compare costs and benefits of different resilience strategies, helping decision-makers weigh short-term expenditures against long-term benefits. By accounting for both direct and indirect benefits, as well as non-disaster impacts, the tool supports investments that strengthen infrastructure and protect the safety of communities. Building on these prior applications, the following section introduces the original case study conducted in this research.

1.3. Riverside County Case Study Overview

Riverside County covers over 7300 square miles (18 907 square kilometers) in Southern California, making it the fourth-largest county in the state and among the largest in the nation. It is home to approximately 2.5 million residents who live in a mix of urban, suburban, agricultural, and desert areas (The County of Riverside, n.d.). This large and diverse area includes parts of the Inland Empire, Coachella Valley, and Colorado Desert, meaning communities face different water needs and natural resource challenges.

Drought is an ongoing problem for the county. According to the U.S. Drought Monitor, as of the most recent drought season (August 2025), every resident experienced drought conditions, with much of the county classified as “severe” or worse in recent years (National Integrated Drought Information System, 2025a). The county’s location east of the coastal mountain ranges places it in a rain shadow, limiting rainfall. This fact, combined with population growth and extensive farming, creates a high demand for the limited water supplies.

Drought conditions tend to reduce plant growth, increases wildfire risk, and threatens the well-being of local wildlife (National Integrated Drought Information System, 2025b). Drought causes lower crop yields, reduces water availability for homes and businesses, increases water costs, and harms public health through heat stress and poor air quality (National Integrated Drought Information System, 2025c).

The county's water system includes imported water pipelines, reservoirs (e.g., Diamond Valley Lake), and groundwater wells. These systems help provide water during dry years but also are not always reliable because they depend on water sources far away and underground aquifers that can be depleted (Metropolitan Water District of Southern California, 2024).

In coming years, drought frequency and severity in Riverside County is expected to increase. Warmer temperatures will increase evaporation and reduce snowpack in the Sierra Nevada, a key source of water for Southern California (California Department of Water Resources, n.d.). This will likely cause longer dry periods and strain water supplies further.

Due to its size, population, diverse land uses, and susceptibility to drought, Riverside County provides a valuable case for examining drought resilience strategies. This study focuses on three approaches – urban landscape conversion, stormwater capture, and purple pipe water recycling – to evaluate their potential benefits for communities facing drought conditions. These three strategies were selected because they are among the most widely recommended strategies for dry areas in Southern California. Each strategy has been identified as a priority in California state water planning documents (California Department of Water Resources, 2025; California Water Boards, 2015; California Water Boards, 2018), and all three are already being implemented to varying degrees across Riverside County, making them practical strategies to evaluate using the EDGe$ platform.

2. Overview of Drought Resilience Strategies

An overview of each drought resilience strategy is provided in this section.

2.1. Urban Landscape Conversion

Urban landscape conversion involves replacing traditional turfgrass with organic, drought-tolerant landscaping, commonly known as xeriscaping, and upgrading irrigation systems to more efficient methods such as drip or micro-spray systems (SoCal Water$mart, 2024). This strategy significantly reduces outdoor water use by choosing plants that grow well in the local climate (National Geographic, n.d.) and cutting down on water lost through heat and sunlight. Studies indicate substantial water savings: for example, xeriscaped areas in Southern Nevada use only about 17 gallons per square foot (0.69 cubic meters/square meters, m^3/m^2) per year, compared with approximately 73 gallons per square foot (2.97 m^3/m^2) per year applied to turfgrass (Sovocool, 2005). As applied in this study, the strategy assumes a program converting 1200 square feet (ft^2) (111 m^2) of turfgrass to drought-tolerant landscaping at 500 single-family homes, totaling 600 000 ft^2 (55 742 m^2; approximately 13.77 acres [5.57 hectares, ha]).

2.2. Stormwater Capture and Reuse Infrastructure

The stormwater capture and reuse strategy involves constructing a basin that collects rainwater and runoff from nearby streets via underground pipes and channels it into ponds, where the water slowly seeps into the ground. This helps reduce flooding and replenishes underground water supplies by using stormwater as a resource instead of letting it flow away as waste (California Water Commission, 2019; United States Environmental Protection Agency, 2025). In this study, the strategy assumes the construction of one recharge basin capable of capturing approximately 400 acre-feet (AF) (493 392 m^3) of stormwater annually. The stormwater basin covers about 20 acres (8.1 ha) and includes conveyance infrastructure to move stormwater from surrounding areas.

2.3. Purple Pipe Water Recycling Networks

Purple pipe water recycling networks involve installing pipelines to deliver treated wastewater for non-potable uses, such as irrigating farmland (Eastern Municipal Water District, 2024). By using recycled water instead of potable water, this approach helps reduce demand on drinking water and supports sustainable water management (Cooley et al., 2019). In this study, the strategy assumes the installation of five miles (8.0 kilometers, km) of purple pipe, along with upgrades to an existing wastewater treatment plant to produce water meeting non-potable reuse standards. The system is assumed to provide approximately 1000 AF (1.23 million m^3) per year, enough to supply around 1600 households or irrigate 500 acres (202 ha).

3. Methodology

This study employs secondary data and publicly available numerical values; no human participants were involved. All data points were selected or estimated from credible sources, such as government reports, to reflect conditions in Riverside County, California.

The analysis was carried out using the EDGe$ platform. Cost, benefit, and externality values described in Section 5 were entered into the software under the planning assumptions outlined in Section 4.

The platform produced economic performance measures including benefit-cost ratios (BCRs), return on investment (ROI), and NPV. These results were used to compare the relative effectiveness of the three drought resilience strategies listed in the previous section.

4. Use Case Assumptions

The following assumptions apply to all three drought resilience strategies evaluated in this study:

- Planning horizon – 20 years
- Drought recurrence – every 5 years
- Real discount rate – 5 % (The Federal Reserve Discount Window, 2024)

In addition, the following assumptions were applied to all strategies to make the approach easier to apply to other areas with similar challenges. The values are illustrative and are not intended as recommendations for actual project planning.

1. All one-time construction or installation costs are assumed to occur in year zero.
2. Operation, maintenance, and repair (OMR) costs are assumed to occur annually, beginning one year after the strategy is put in place.
3. The analysis focuses on drought events severe enough to cause noticeable impacts. Smaller, less disruptive dry periods are not included.
4. All strategies are compared to a baseline scenario of taking no new action and maintaining current practices.
5. Population and water demand are assumed to remain constant over the 20-year period.

5. Data Inputs

5.1. Cost Data

For all three drought resilience strategies, costs are categorized into immediate direct, immediate indirect, and OMR.

5.1.1. Urban Landscape Conversion

Immediate direct costs for urban landscape conversion include turf removal and re-landscaping, which covers labor, drought-tolerant plants, mulch, and installation materials. Xeriscaping costs typically range from \$5 to \$20 per square foot (0.09 m^2); an average value of \$12.50 per square foot (0.09 m^2) was applied, resulting in an estimated \$7 500 000 for the total program area (Caayao, 2024).

A drip irrigation retrofit is also included to improve watering efficiency and reduce waste. Installation costs range from \$0.50 to \$3.00 per square foot (0.09 m^2); using an average of \$1.75 per square foot (0.09 m^2) yields \$1 050 000 for the total area (Gordon, 2025).

Immediate indirect costs include permit fees, inspections, design approvals, and program administration. Based on Riverside County rebate program documentation, these costs are estimated at \$400 per home, totaling \$200 000 (Addink, 2023).

Operation, maintenance, and repair costs reflect the upkeep required for drought-tolerant landscaping, such as mulch replacement and pruning. Annual maintenance costs average \$0.28 per square foot (0.09 m^2), resulting in \$168 000 per year over the 20-year study period (Brashear, 2025). These recurring costs are discounted in the EDGe\$ analysis.

A summary of cost categories is presented in Table 1.

Table 1. Costs for Urban Landscape Conversion.

Category	Item	Calculation	Cost
Immediate Direct	Turf Removal & Re-landscaping	\$12.50/ft² (0.09 m²) x 600 000 ft² (55 742 m²)	\$7 500 000
	Drip Irrigation Retrofit	\$1.75/ft² (0.09 m²) x 600 000 ft² (55 742 m²)	\$1 050 000
Immediate Indirect	Permit, Inspection & Design Approval	\$400/home x 500 homes	\$200 000
OMR	Maintenance (plants, mulch, etc.)	\$0.28/ft² (0.09 m²)/year x 600 000 ft² (55 742 m²)	\$168 000 annually

5.1.2. Stormwater Capture and Reuse Infrastructure

For the stormwater capture and reuse strategy, immediate direct costs include digging the basin and constructing the conveyance system. Based on reported median construction costs for similar-scale projects, a unit cost of $1250 per AF (1233 m³) was applied, resulting in $500 000 for the planned 400 AF (493 392 m³) capacity (Southern California Water Coalition, 2018; Diringer et al., 2020).

Design and permitting costs include conducting engineering surveys, hydrologic modeling, and filing paperwork for approval. These were estimated at $250 000 as a lump sum to reflect typical project design and regulatory costs in California.

Immediate indirect costs include land acquisition for the 20-acre (8.1 ha) basin site, assuming the land is not already publicly owned. Land value in Riverside County varies, with recent averages ranging from approximately $21 000 to $66 800 per acre (0.40 ha). An assumed value of $44 000 per acre (0.40 ha) results in an estimated $880 000 for the site (Land.com Network, 2025; LandSearch, 2025).

Temporary disruptions to nearby businesses during construction are also considered. These include road closures and restricted customer access. Using an average business annual revenue of about $1.22 million and assuming a 2 % revenue loss during construction, the estimated impact is $24 438 per business. For an assumed 15 affected businesses, the total disruption cost is $366 570 (Radin & Ray, 2011; Vena Solutions, 2025).

OMR costs are assumed at 10 % of total capital costs annually. This covers the removal of sediment, trimming of vegetation, and clearing of debris to ensure the system continues to operate properly. Based on total capital costs of $1 996 570, annual maintenance is estimated at $199 657.

Table 2 displays the cost categories for this investment strategy.

Table 2. Costs for Stormwater Capture and Reuse Infrastructure.

Category	Item	Calculation	Cost
Immediate Direct	Basin & Conveyance Construction	$1250/AF (1233 m³) x 400 AF (493 392 m³)	$500 000
	Design & Permit	-	$250 000 (estimate)
Immediate Indirect	Land Acquisition	$44 000/acre (0.40 ha) x 20 acres (8.1 ha)	$880 000
	Construction Impacts	$24 400/business x 15 businesses (assume 15 businesses impacted)	$366 570
OMR	Maintenance	$1 996 570 x 10%	$199 657 annually

5.1.3. Purple Pipe Water Recycling Network

Immediate direct costs for the installation of a purple pipe water recycling network include pipeline installation and treatment upgrades. Installation of recycled water pipeline, which cannot be integrated with potable water systems, is estimated at \$2 million per mile (1.61 km). For a five-mile (8.0 km) project, the total cost is \$10 000 000 (San Diego Coastkeeper, 2011). Treatment plant upgrades – like improving filtration, disinfecting with ultraviolet light, or treating with chlorine – are estimated at \$950 per AF (1233 m³). For 1000 AF (1.23 million m³) of annual output, the cost is \$950 000 (Cooley et al., 2019).

Immediate indirect costs account for construction impacts and public coordination. Pipeline installation typically disrupts traffic, utilities, and customer access for adjacent businesses. Based on an average business annual revenue of \$1.22 million and an assumed 2 % revenue loss during the construction period, the impact per business is \$24 438. For 15 affected businesses, the total cost is approximately \$366 570 (Radin & Ray, 2011; Vena Solutions, 2025). Public coordination, including outreach to agencies and contractors, is estimated at a lump sum of \$500 000 (Eastern Municipal Water District, 2016).

OMR costs come from annual inspection, leak detection, valve testing, and minor repairs. Annual maintenance is estimated at \$60 000 per year over the 20-year planning horizon (Oro Loma Sanitary District, 2020).

The costs of installing a purple pipe water recycling network are displayed in Table 3.

Table 3. Costs for Installation of Purple Pipe Water Recycling Network

Table 3. Costs for Installation of Purple Pipe Water Recycling Network.

Category	Item	Calculation	Cost
Immediate Direct	Pipe Installation	\$2 000 000/mile (1.61 km) x 5 miles (8.0 km)	\$10 000 000
	Treatment Upgrades	\$950/AF (1233 m³) x 1000 AF (1.23 million m³)	\$950 000
Immediate Indirect	Construction Impacts	\$24 400/business x 15 businesses (assume 15 businesses impacted)	\$366 570
	Public Coordination	-	\$500 000 (estimate)
OMR	Maintenance	\$60 000/year	\$60 000 annually

5.2. Disaster-Related Benefits

This section estimates how much disaster-related loss each drought resilience strategy could help avoid. This study applied percentages to the initial investment costs for each strategy to represent the value of reduced damage, fewer disruptions, and faster recovery after drought events. These percentages are based on findings from national studies of hazard mitigation, which suggest that investments in resilience tend to save more than the amount spent by preventing or reducing losses. Because exact BCRs for drought resilience strategies are not always explicitly available in the literature, the percentages used here are based on national hazard mitigation studies and adjusted to reflect what each strategy is expected to contribute to in regards to direct, indirect, and response and recovery benefits.

Spending on flood adaptations typically reduces expected damage by about two to three times the amount invested (Congressional Budget Office, 2024). Similarly, the National Institute of Building Sciences (NIBS), in partnership with the Federal Emergency Management Agency (FEMA), reports that federal grants for hazard mitigation save an average of six dollars for every dollar spent (NIBS, 2025). Risk mitigation saves money by lowering damages and recovery costs for extreme weather impacts, such as drought.

5.2.1. Urban Landscape Conversion

For urban landscape conversion, the estimated direct benefits equal about 150 % of the initial investment. This assumes that each dollar spent saves about $1.50 by reducing water-damage risk during droughts, yielding a BCR of approximately 1.5:1.0. This estimate is lower than what the broader hazard mitigation literature suggests (NIBS, 2025; Congressional Budget Office, 2024), as landscape conversion primarily reduces water demand rather than providing physical protection against damage caused by droughts. Indirect benefits are estimated at 20 % of the program cost, based on the idea that as more people participate, the overall landscaping risk in the community decreases beyond just those directly involved. Response and recovery benefits are calculated at about twice the investment cost, representing savings from faster recovery and having extra water available during droughts.

Table 4 summarizes these estimates for urban landscape conversion.

Table 4. Event-Related Benefits for Urban Landscape Conversion.

Loss Category	Calculation	Loss Reduction
Direct	150 % of direct costs (turf; irrigation)	$12 825 000
Indirect	20 % of direct costs (turf; irrigation)	$1 710 000
Response & Recovery	200 % of direct costs (turf; irrigation)	$17 100 000

5.2.2. Stormwater Capture and Reuse Infrastructure

Direct benefits are estimated at 200 % of the capital costs related to construction, permitting, and land acquisition. This assumes a BCR of approximately 2.0:1.0, based on evidence from flood mitigation studies showing that every dollar invested typically avoids two dollars in damage (Congressional Budget Office, 2024). Indirect benefits are estimated at 50 % of the capital costs, accounting for additional positive effects like a more reliable groundwater supply. Response and recovery benefits are also estimated at 200 % of capital costs to reflect faster recovery after flood events.

Table 5 displays the event-related benefits of this drought resilience strategy.

Table 5. Event-Related Benefits for Stormwater Capture and Reuse Infrastructure.

Loss Category	Calculation	Loss Reduction
Direct	200 % of capital costs (construction; permitting; land)	$3 260 000
Indirect	50 % of capital costs (construction; permitting; land)	$815 000
Response & Recovery	200 % of capital costs (construction; permitting; land)	$3 260 000

5.2.3. Purple Pipe Water Recycling Networks

For purple pipe water recycling networks, direct benefits are estimated at 150 % of the initial costs for pipe installation and treatment upgrades. This estimate reflects the value of improved water supply reliability and reduced risk of shortages during droughts. Indirect benefits are calculated as 50 % of the direct costs to account for environmental benefits like reduced demand for freshwater sources. Response and recovery benefits are estimated at 250 % of the initial costs to represent faster recovery during drought and the availability of an alternate water supply. Research on water recycling systems supports the higher response and recovery estimate, as investments in such infrastructure have been shown to significantly reduce the reliance on imported water and help communities avoid severe water shortages over time (Chow et al., 2024).A summary of the event-related benefits of purple pipe water recycling networks is provided in Table 6.

Table 6. Event-Related Benefits for Purple Pipe Water Recycling Networks.

Loss Category	Calculation	Loss Reduction
Direct	150 % of direct costs (pipes; treatment)	$16 425 000
Indirect	50 % of direct costs (pipes; treatment)	$5 475 000
Response & Recovery	250 % of direct costs (pipes; treatment)	$27 375 000

5.3. Non-Disaster-Related Benefits

In resilience planning, non-disaster-related benefits (i.e., co-benefits), are positive outcomes that arise when no disruptive event (e.g., drought) occurs. The net value of these benefits determines the resilience dividend. As described by Fung and Helgeson (2017) and further developed by Helgeson et al. (2025), the resilience dividend represents the additional benefits gained from investing in resilience, even when a disaster does not occur. This includes benefits that improve daily well-being or the community’s circumstances in general, beyond avoided losses during and after disasters.

5.3.1. Urban Landscape Conversion

Urban landscape conversion to drought-tolerant xeriscaping yields notable day-to-day benefits for the community beyond disaster resilience. One of the largest direct economic benefits is the reduction in homeowner landscaping costs. For traditional landscaping, maintenance averages $9600 annually; xeriscaping reduces these costs by approximately 55 %, resulting in an annual savings of $5280 per household (Çetin et al., 2018; Grupa, 2025). For the 500 properties, this equates to $2 640 000 in savings per year throughout the 20-year planning horizon.

In addition to cost savings, urban landscape conversion provides environmental benefits and supports biodiversity. Using FEMA's value of $2420 per acre (0.40 ha) per year for land comparable to coastal wetlands (FEMA, 2022), the converted 13.77 acres (5.57 ha) provide an estimated $33 324 annually in environmental benefits. This improves soil health and biodiversity.

Urban heat mitigation and improved air quality also represent recurring benefits. Based on FEMA's ecosystem service value of approximately $200 per acre (0.40 ha) per year (FEMA, 2022), the 13.77 acres (5.57 ha) of drought-tolerant landscaping yield approximately $2754 annually in reduced cooling energy use and associated pollutants. These co-benefits contribute to improved public health and reduced urban heat island effects, creating a more comfortable and sustainable community environment year-round.

Table 7 provides a summary of the non-disaster-related benefits of urban landscape conversion.

Table 7. Non-Disaster-Related Benefits of Urban Landscape Conversion.

Item	Calculation	Benefit
Homeowner Landscaping Cost Savings	$5280/home x 500 homes	$2 640 000 annually
Improved Biodiversity and Ecosystem	$2420/acre (0.40 ha)/year x 13.77 acres (5.57 ha)	$33 324 annually
Urban Heat Mitigation & Air Quality Improvement	$200/acre (0.40 ha)/year x 13.77 acres (5.57 ha)	$2754 annually

5.3.2. Stormwater Capture and Reuse Infrastructure

Stormwater capture and reuse infrastructure provides non-disaster benefits that improve local water reliability, increase property value, and contribute to public health. For the project modeled in this study, collecting roughly 400 AF (493 392 m^3) per year, and valuing that stored water at $200 per AF (1233 m^3) yields about $80 000 per year in benefits from enhanced local supply and recharge (California Stormwater Quality Association, 2024).

The stormwater recharge basin can also increase nearby property values (California Stormwater Quality Association, 2024); using a value of $500 per acre (0.40 ha) per year across the 20-acre (8.09 ha) site gives an estimated $10 000 per year in property value increase for this project. Parks and open areas located near the basin also provide recreational and public-health value as well (California Stormwater Quality Association, 2024); applying an estimate of $250 per acre (0.40 ha) per year yields roughly $5000 per year.

A summary of the non-disaster related benefits for this strategy is provided in Table 8.

Table 8. Non-Disaster-Related benefits for Stormwater Capture and Reuse Infrastructure.

Item	Calculation	Benefit
Improved Water Supply Reliability and Local Recharge	Assume $200/AF (1233 m³)/year x 400 AF (493 392 m³)	$80 000 annually
Property Value Increase	Assume $500/acre (0.40 ha)/year x 20 acres (8.09 ha)	$10 000 annually
Public Health and Recreational Benefits	Assume $250/acre (0.40 ha)/year x 20 acres (8.09 ha)	$5 000 annually

5.3.3. Purple Pipe Water Recycling Networks

Purple pipe water recycling networks offer non-disaster benefits by reducing potable water system demands, lowering pollutants, and enhancing public engagement with water sustainability. The avoided potable water cost is calculated using the San Diego County Water Authority's rate of approximately $1929 per AF (1233 m³) for treated water (San Diego County Water Authority, 2022), with energy-related costs representing roughly 20 % of this value. This yields an avoided treatment and pumping cost of about $390 per AF (1233 m³); applied to an annual volume of 1000 AF (1.23 million m³), the resulting savings are approximately $390 000 per year.

Energy savings from reduced potable water treatment and pumping also lead to avoided pollutants. Valued at approximately $50 per AF (1233 m³), the avoided pollutants benefit from recycling 1000 AF (1.23 million m³) per year totals about $50 000 annually. In addition, the purple pipe systems can provide a valuable way to educate the community. By hosting school visits, workshops, and public tours, purple pipe systems can enhance public understanding of water reuse and conservation. This is estimated at $100 000 as a one-time benefit over the project life.

Table 9 summarizes the non-disaster-related benefits of installing purple pipe water recycling networks.

Table 9. Non-Disaster-Related Benefits of Purple Pipe Water Recycling Networks.

Item	Calculation	Benefit
Reduced Treatment, Pumping and Energy Demand	$390/AF (1233 m³)/year x 1 000 AF (1.23 million m³)	$390 000 annually
Pollutants Reduction Via Avoided Energy Use	Assume $50/AF (1233 m³)/year x 1 000 AF (1.23 million m³)	$50 000 annually
Public Awareness & Education Through Demonstration	-	$100 000 (estimate)

5.4. Externalities

Externalities refer to the unintended side effects of an economic activity that affect third parties who are not directly involved in the transaction. These effects can be either positive or negative, and third parties are not directly compensated. As discussed by Fung and Helgeson (2017), externalities are part of the broader resilience dividend, which includes co-benefits realized even without a disaster.

5.4.1. Urban Landscape Conversion

For the urban landscape conversion strategy, several externalities were identified that influence community and environmental well-being. One positive externality is the reduction in potable water usage at the community level, estimated at approximately $6150 annually due to decreased demand associated with converting turf to drought-tolerant landscaping. This estimate is based on water savings of 72 to 95 liters per square meter in similar cities (Cooley et al., 2019). Another positive externality is the increase in homeowner property values attributed to improved landscaping, which can raise median home prices by 5 to 15 %. Using a 10 % increase on a median home price of $619 000 for 500 homes results in a one-time positive externality valued at nearly $31 million (Gorski, 2025; Realtor.com, 2025).

However, some negative externalities also occur, such as aesthetic losses. Turf removal may temporarily reduce the scenic quality of the environment by an estimated $52 000 annually, totaling about $156 000 during this period.

5.4.2. Stormwater Capture and Reuse Infrastructure

Several externalities affect the surrounding community and environment for this strategy. One positive externality is the avoided flood damage downstream, which provides a recurring benefit estimated at approximately $18 600 annually. This estimate is based on flood mitigation values of about $2300 per ha of wetland per year, applied to the 8.1 ha covered by the stormwater basin (Taylor & Druckenmiller, 2022).

Another positive externality is the improvement in water quality through nutrient and sediment removal provided by the stormwater infrastructure. This benefit is estimated at $10 000 per year for the 20-acre site (8.1 ha).

However, there is a negative externality related to the opportunity cost of land use. The 20 acres (8.1 ha) used for the stormwater basin could alternatively be used for development or generate tax revenue. Based on an average land value of $44 000 per acre (0.40 ha) in Riverside County, this results in a one-time cost of $880 000 representing lost potential income for landowners (Land.com Network, 2025; LandSearch, 2025).

5.4.3. Purple Pipe Water Recycling Networks

For the purple pipe water recycling networks, positive externalities include savings from avoided potable water use and improved environmental quality from reduced wastewater discharge. The avoided potable water usage is valued at approximately \$1 500 000 annually, calculated by multiplying the 1000 AF (1.23 million m^3) per year supplied by the system by an estimated cost of \$1500 per AF (1233 m^3).

Additionally, reducing wastewater discharge improves the quality of the environment by decreasing pollutants. This benefit is estimated at \$200 000 annually, based on 1000 AF (1.23 million m^3) per year valued at \$200 per AF (1233 m^3).

The net externalities for each of the drought resilience strategies are displayed in Table 10.

Table 10. Net Externality for Each Drought Resilience Strategy.

Drought Resilience Strategy	Net Externality
Urban Landscape Conversion	\$30 917 000
Stormwater Capture and Reuse Infrastructure	-\$308 000
Purple Pipe Water Recycling Networks	\$34 000 000

6. Results

After entering all inputs described in Section 5 into the EDGe$ Online Tool, the program produced a full set of benefit-cost calculations for each investment option. Table 11 summarizes the results, where Option 1 represents Urban Landscape Conversion, Option 2 represents Stormwater Capture and Reuse Infrastructure, and Option 3 represents Purple Pipe Water Recycling Networks.

Table 11. Output of the EDGe$ Tool.

	Option 1	Option 2	Option 3
Disaster Economic Benefits			
Response and Recovery Costs	$43 240 000	$8 240 000	$69 220 000
Direct Loss Reduction	$32 430 000	$8 240 000	$41 530 000
Indirect Losses	$4 320 000	$2 060 000	$13 840 000
Disaster Non-Market Benefits			
Value of Statistical Lives Saved	$0	$0	$0
Number of Statistical Lives Saved	0	0	0
Non-Disaster Related Benefits			
One-Time	$0	$0	$100 000
Recurring	$32 990 000	$1 170 000	$5 420 000
Costs			
Direct Costs	$8 550 000	$750 000	$10 950 000
Indirect Costs	$200 000	$1 250 000	$680 000
OMR			
One-Time	$0	$0	$0
Recurring	$2 070 000	$2 460 000	$740 000
Externalities			
Positive			
One-Time	$29 440 000	$0	$0
Recurring	$80 000	$350 000	$20 960 000
Negative			
One-Time	$140 000	$840 000	$0
Recurring	$0	$0.00	$0
Present Expected Value			
Benefits	$112 980 000	$19 720 000	$130 110 000
Costs	$10 820 000	$4 460 000	$12 370 000

Externalities	$29 380 000	-$480 000	$20 960 000
With Externalities			
Net NPV	$131 540 000	$14 780 000	$138 700 000
Benefit-to-Cost Ratio	13.16	4.31	12.21
Internal Rate of Return (%)	Infinite	56.49	95.70
Annual Return on Investment (%)	60.78	16.57	56.05
Annual Non-Disaster ROI (%)	23.82	-4.23	5.70
Without Externalities			
Net (NPV)	$102 160 000	$15 260 000	$117 740 000
Benefit-to-Cost Ratio	10.44	4.42	10.52
Internal Rate of Return (%)	89.99	69.85	87.08
Annual Return on Investment (%)	47.20	17.11	47.58
Annual Non-Disaster ROI (%)	10.24	-3.69	-2.77

Note: Monetary values are rounded to the nearest $10 000 and may not sum exactly due to rounding.

The results in the table above indicate that Options 1 and 3 are preferred investments compared to Option 2. With externalities included, Option 3 has the highest Net Present Value (NPV) at $138 700 000, followed by Option 1 at $131 540 000, while Option 2 is significantly lower at $14 780 000. This ranking remains the same when externalities are excluded, with Option 3 at $117 740 000, Option 1 at $102 160 000, and Option 2 at $15 260 000. A similar pattern is observed for ROI. With externalities, Option 1 and Option 3 have the highest annual ROI values (60.78 % and 56.05 %, respectively), compared to 16.57 % for Option 2. Without externalities, Option 1 and Option 3 continue to outperform Option 2, with annual ROI values of 47.20 % and 47.58 %, respectively, versus 17.11 %.

The non-disaster ROI, however, highlights differences between Options 1 and Option 3. Option 1 is positive with externalities (23.82 %) and without externalities (10.24 %). In contrast, Option 3 is only slightly positive with externalities (5.70 %) and turns negative without them (-2.77 %). Option 2 is negative in both cases (-4.23 % with externalities, -3.69 % without).

Overall, Urban Landscape Conversion (Option 1) is the optimal strategy followed by Option 3, while Option 2 is least preferred. Option 1 is preferred because it maintains positive non-disaster ROIs in all cases, whereas Option 3 only does so when externalities are included.

7. Discussion

The findings from the previous section reveal that an urban landscape conversion project in Riverside County, California converting 1200 ft² (111 m²) of turfgrass to drought-tolerant landscaping at 500 single-family homes is the most promising investment out of the three options. The total upfront costs for turf removal, drip irrigation retrofits, and permitting total $8.75 million, with another $3.36 million in maintenance over 20 years. In return, the strategy produces nearly $80 million in reduced disaster damages and recovery costs and another $33 million in ongoing non-disaster benefits from reduced water use and energy savings. When externalities such as avoided pollutants are included, the present value of benefits reaches nearly $113 million compared to about $10.8 million in costs. This results in a BCR of over 13 and an ROI of over 60 % annually with externalities. Even without externalities, the benefit-cost ratio is just over 10, with an ROI of about 47 % per year. These results confirm that landscape conversion is a cost-effective drought resilience strategy with returns well above its initial investment.

These results show that strategies like turf replacement can provide strong returns in practice. Through the SoCal Water$mart program, Southern California agencies have offered rebates to homeowners who replace grass lawns with drought-tolerant landscaping (SoCal Water$mart, 2024). In Los Angeles, there are rebates of up to $5 per square foot (0.09 m²), making these changes more affordable for residents (Los Angeles Department of Water and Power, 2024). Programs like this have helped reduce outdoor water use and cut down on long-term costs, which supports the findings from this case study that landscape conversion is an effective resilience strategy.

At the state level, the California Department of Water Resources has launched a turf replacement pilot program that installs drought-tolerant landscaping at no cost in certain communities, with a goal of completing projects by 2027 (California Department of Water Resources, 2025). Meanwhile, in 2023, the Metropolitan Water District received $38 million in state funding through the California Department of Water Resources' Urban Community Drought Relief program to expand turf replacement incentives, increasing rebates per square foot and aiming to remove tens of millions of square feet of grass (Valdes et al., 2023). These efforts align with the results of this analysis by showing how turf replacement is being implemented as a long-term drought resilience strategy across California.

This study has some limitations. The analysis relied only on data that is publicly available from government reports, published studies, and other secondary sources, which means some relevant costs or benefits may be missing, potentially leading the results to understate the full value of these investments. Because this is a case study, the findings are specific to Riverside County and may not fully apply to other regions. Additionally, not every factor influencing outcomes could be included in this analysis. For example, variations in local drought conditions or water prices. Thus, the results should be interpreted as a useful illustration rather than a complete representation of the county's resilience planning.

Even with these limitations, the case study highlights the value of the EDGe$ tool for comparing drought resilience strategies. Future work that involves collaboration with local planners could help build on these results. The results highlight the importance of considering more than just direct costs in resilience planning. Factoring in non-disaster benefits and externalities provides a clearer picture of an investment's overall value. Looking ahead, using tools like EDGe$ to evaluate different options can help decision-makers choose investments that benefit communities in both the short and long term.

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