Restoration of aging concrete channels through a watershed-scale approach to green infrastructure: a framework and case-study in a suburban California watershed

Restauration de canaux bétonnés vieillissants en infrastructure verte à l'échelle du bassin versant : cadre d'étude et étude de cas dans un bassin-versant suburbain de la Californie

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RÉSUMÉ

Alors que les districts de contrôle des inondations et les autorités de planification dans les bassins versants « suburbanisés » cherchent à aborder la question des canaux bétonnés vieillissants conçus pour la protection contre les inondations, les modèles de développement existants limitent les possibilités de restauration des canaux et les processus qui soutiennent les ruisseaux autosuffisants. La restauration stratégique des réseaux de drainage urbanisés des basses terres dans un bassin versant peut rendre possible une infrastructure « verte » rentable qui réintègre l'infiltration, la recharge des eaux souterraines, les plaines inondables saisonnières et les processus de transport des sédiments dans l'empreinte urbaine. Malgré le besoin critique d'amélioration des canaux de contrôle des inondations et l'intérêt pour leur conversion en corridors de ruisseaux multifonctionnels, il existe peu de cadres de référence pour aider les gestionnaires de la lutte contre les inondations ou les autorités de planification à élaborer des stratégies appropriées. Nous présentons un cadre pour la priorisation de la restauration des canaux en béton et des interventions dans les bassins versants pour favoriser le transport sur les ruisseaux, le stockage saisonnier des crues et l'infiltration pour la recharge des eaux souterraines. A partir de publications scientifiques, nous avons développé des critères d'adéquation pour la naturalisation des ruisseaux, l'expansion des plaines inondables et l'infiltration. Nous démontrons comment ces critères peuvent être utilisés pour identifier les zones présentant des avantages écologiques et sociaux qui se chevauchent et comment le cadre peut être appliqué en donnant l'exemple d'une étude de cas sur le bassin hydrographique de Walnut Creek dans la baie de San Francisco en Californie, aux Etats-Unis.

ABSTRACT

As flood control districts and planning authorities in suburbanized watersheds seek to address aging concrete flood control channels, existing development patterns limit opportunities to restore channels and the processes that support self-sustaining creeks. The strategic restoration of urbanized lowland drainage networks throughout a watershed can support cost-effective “green” infrastructure (GI) that re-integrates infiltration, groundwater recharge, seasonal floodplains and sediment transport processes into the urban footprint. Despite the critical need for flood control channel upgrade and interest in conversion to multi-functional creek corridors, there are few frameworks to assist flood control managers or planning authorities in developing appropriate strategies for channel restoration. We present a framework for prioritizing concrete channel restoration and watershed interventions to support creek conveyance, seasonal flood storage, and infiltration for groundwater recharge. Informed by scientific literature, we developed suitability criteria for creek naturalization, floodplain expansion, and infiltration. We show how criteria can be used to identify areas with overlapping ecological and social benefits of creek naturalization, and demonstrate how the framework can be applied using a case study of Walnut Creek Watershed in the San Francisco Bay Area of California, U.S.A.

KEYWORDS

Urban streams; concrete channels; flood protection; green infrastructure; watershed restoration

1 INTRODUCTION

Re-integration of ecological functions into suburbanized watersheds with hardened flood control infrastructure requires an analysis of the social and ecological trade-offs of potential functions, benefits and services across multiple scales. Functioning watersheds and creeks provide services to support humans as part of a sustainable, healthy urban ecosystem, which in turn have value as direct benefits to society. Benefits of an integrated, multi-functional creek corridor can be expressed along a spectrum from social to ecological benefits: accessible recreation and leisure, aesthetics, community desirability, increased property values, green job development, strengthened sense of place and community identity, educational opportunities, integrated urban water filtration for improved water quality, more robust wildlife habitat. Besides the many social and ecological benefits, implementation of urban creek corridor restoration is also an exercise in understanding the risks associated with decision making in the face of uncertainty. These risks and uncertainties represent those of aging built infrastructure, stormwater pollution, natural infrastructure alternatives, fiscal resources, water resources, climate change, and climate variability.

Despite the uncertainties and perceived risks associated with natural infrastructure, its overlapping public and ecological benefits present opportunities to support community interests and expand stakeholder and funder networks. Flood control districts, planning authorities, and water resources managers are increasingly turning towards natural infrastructure, green infrastructure, and low impact development as cost-efficient and adaptive management tools (Gartner, Mulligan, Schmidt, & Gunn, 2013). This shift towards natural infrastructure is not without challenges. As flood control districts seek to replace aging, single-purpose “gray” infrastructure with multi-functional green infrastructure, existing development limits options to restore natural, self-sustaining creeks. Fragmented regulation, politics, and stove-piped institutional structures challenge attempts to adjust land use and invest in watershed services that can sustain communities through drought and flood. Current approaches to urban creek restoration target opportunistic, site-based projects resulting in isolated reaches that fail to connect to former floodplains or address impacts of urbanization in upstream contributing areas. Planning for restoration of urbanized lowland drainage networks requires a strategic approach to consider how underlying biophysical conditions throughout a watershed can support cost-effective green infrastructure that re-integrates infiltration, groundwater recharge, seasonal floodplains and sediment transport processes into the urban footprint.

2 METHODS

We propose a framework for urban stream restoration that uses accessible geospatial data to identify strategic target areas to support key functions of urban watersheds. We used a four-phase approach for identifying priority reaches for restoration based on: multi-functional creek conveyance potential, seasonal flood storage potential, watershed infiltration potential, and a watershed-scale comprehensive overview of results with high level opportunities, limitations, and strategies for achieving restoration along high priority reaches (Figure 1).

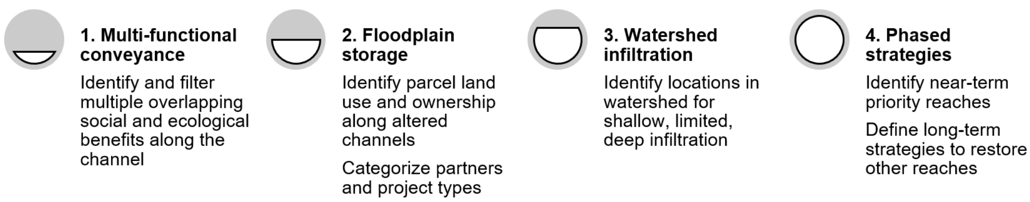

Figure 1. Four Phases For Channel Restoration Priorities

2.1 Phase 1 : Multi-Functional Creek Conveyance

Our phase 1 prioritization defines categories of benefits, determines spatial extent of each benefit, and counts the number of overlapping benefits along the creek corridor. We defined categories of benefits that can address issues related to reduced ecosystem and social services of local creeks due to channel confinement, reduced dynamics and complexity, disconnection with historical floodplain and limited public access. We assigned a reach priority based on the number of overlapping areas associated with five potential benefits: the more overlapping benefits, the higher priority.

- **Benefit 1.** Baseline: existing channel is concrete, riprap, or earthen (constructed)
- **Benefit 2.** Floodplain Expansion: channel is within 500-year floodplain or historic floodplain
- **Benefit 3.** Community: channel is adjacent to high community demand, high circulation demand, or high anticipated demand area
- **Benefit 4.** Environmental Justice: channel is adjacent to a community of concern, air quality

concern, low park accessibility, or high flood risk area
- **Benefit 5.** Ecology: channel historically supported a migratory salmonid population or is underlain by permeable soils that promote groundwater-surface water interaction

2.2 Seasonal Floodplain Storage

Realistic and strategic restoration planning in densely urbanized areas requires consideration of existing land uses and land owners within the channel and floodplain. We explored how to implement restoration according to land uses and stakeholder interests with attention to parcel layouts and jurisdictions. Key stakeholders who may own large areas within a watershed include:

- Flood Control District or Planning Authority
- Educational Partners (school districts, public/private schools and colleges)
- Publicly Owned Parcels (county, government, or municipality)
- Under-used parcels (vacant or parking lots)

We refer to these key stakeholders as “Parcel Partners” as they represent land owners that may be more willing, able, and incentivized to participate in creek restoration, green infrastructure, and community connectivity projects. Parcels within jurisdictions with higher capacity to implement restoration projects or offer opportunities for longer-term solutions such as land-use mechanisms and creek ordinances are referred to as “high institutional capacity” parcels. Parcels owned by the flood control district or planning authority (Figure 2; dark hatch) and parcel partners (Figure 2; light hatch) within the altered channel and the floodplain are used to identify opportunities for both in-channel restoration (i.e., removal of concrete channel, natural channel stabilization, native plantings) and floodplain expansion vs. areas just for in-channel restoration.

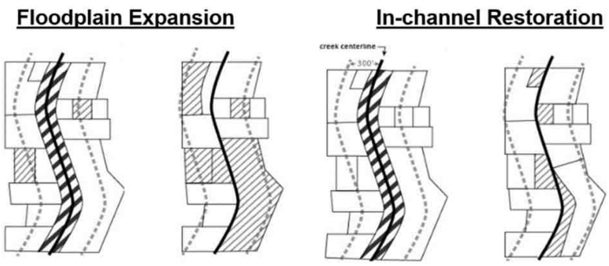

Figure 2. Floodplain Expansion and In-channel Opportunities

2.3 Watershed Infiltration

The long-term restoration of urbanized channels depends heavily on the watershed capacity to promote and sustain long-term ecosystem functions. Previous research shows that stormwater infiltration can treat stormwater runoff, increase recharge, and reduce peak flows (Jefferson et al., 2017). Thus, we developed a process to identify suitable locations for watershed-scale mitigation of urban land use impacts on water quality and hydroregime. Specifically, we assessed suitability of:

- Shallow infiltration facilities, such as bioretention, permeable pavement, infiltration trenches
- Deep infiltration facilities, which consist of deep drains to convey stormwater past surface soil layers with lower infiltration rates into deep, unsaturated, permeable layers
- Limited infiltration facilities, in which infiltration is only limited by presence of low permeability soils

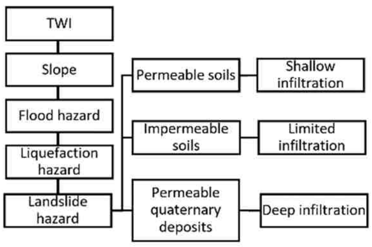

Figure 3. Infiltration Suitability Process

We identified, ranked, and overlayed seven biophysical criteria that restrict or allow for shallow, limited, or deep infiltration opportunities (Figure 3). Infiltration opportunities are identified within hydrologic soil groups A and B (permeable soils), limited infiltration areas within hydrologic soil group C (relatively impermeable soils, where elevated underdrains or oversized facilities possible). In areas with low permeability soils (soil group C and D), deep infiltration is an option if permeable geology allows for infiltration to deeper soil layers.

2.4 Phased Strategies

Watershed-wide restoration of engineered channels requires a phased approach to restoration planning that builds engaged and sustained stakeholder partnerships. By overlaying the results of the three prioritization phases, we identified restoration projects and reaches that should be implemented immediately, that should be implemented last, and that require more strategic partnerships. In this process, high priority reaches with multiple overlapping reach-scale benefits, floodplain expansion potential, and upgradient infiltration opportunities rise to the top, and low priority reaches with limited benefits, no floodplain expansion potential, and no infiltration opportunities fall to the bottom. The reaches in between require more strategic planning over the long term. Here, the planning authority should target the identified partnerships in areas with high multi-functional creek conveyance potential or infiltration suitability potential.

2.5 Case Study: Walnut Creek Watershed

Contra Costa County, in the East San Francisco Bay area, is one example of a suburbanized municipality struggling with increased flood risk, stormwater pollution, aging infrastructure, infill pressure, and environmental justice concerns in developed floodplain corridors. To protect life and property in this floodprone area, the Contra Costa County Flood Control and Water Conservation District (District) owns and manages 80 miles of flood control channels and 30 detention basins within nine distinct watersheds built over the past sixty-five years. In 2009, the District defined and adopted a "50 Year Plan" to prioritize concrete channel removal, creek restoration, and floodplain expansion in their capital replacement plans (Contra Costa County Flood Control and Water Conservation District, 2009). The 50 Year Plan calls for conversion of engineered channels, which serve one primary purpose: flood control and protection; to multi-functional, multi-benefit green infrastructure, which serves both human and ecological communities. Our research partnership between UC Berkeley and Contra Costa County Flood Control and Water Conservation District allowed for development and testing of this framework using Walnut Creek Watershed as a case study.

3 RESULTS AND DISCUSSION

At 146 square miles, Walnut Creek Watershed is the largest watershed in Contra Costa County, and is comprised of seven urban cities, 300 miles of creek corridor, 90 miles of altered channels, and five subwatersheds. Applying the urban stream restoration framework to Walnut Creek watershed identified restoration priority along the channel corridor at four scales: channel, floodplain, watershed, and time.

Our results from the multi-functional creek conveyance process (phase 1) show that the longest reaches of channel with most overlapping benefits lie along the main channel of Walnut Creek. In total, 23 percent of all altered channels have high potential for multi-functional creek conveyance (with all five overlapping benefits). Results of the seasonal floodplain storage process (phase 2) reveal opportunities for floodplain expansion and in-channel restoration in the lower watershed, and for longitudinal connection of floodplain expansion reaches with in-channel restoration reaches. This could help increase social and physical connections to the creek corridor and floodplain. In total, 36 percent of altered channels have opportunities for floodplain expansion and 6 percent are limited to in-channel restoration efforts; the remaining reaches have limited in-channel or floodplain restoration potential. Our watershed infiltration analysis (phase 3) indicates that limited opportunities exist for shallow surface infiltration due to low permeability soils, liquefaction, and steep slopes; however, permeable quaternary deposits present opportunities for deep stormwater infiltration where shallow infiltration may be infeasible. Only about 2 percent of the watershed area is highly suitable for shallow infiltration; while 24 percent and 21 percent of the watershed area is highly suitable for limited infiltration and deep infiltration, respectively.

By overlapping these results (phase 4), we identified multiple high priority projects that promise multi-functioning creek corridors and floodplain storage in the lower watershed (for immediate implementation), a number of high benefit reaches that require strategic partnerships over the long term, and fewer low priority reaches in the upper watershed. In areas with low opportunity for floodplain expansion or in-channel restoration, we can look to strategic partnerships within jurisdictions that have higher capacity to implement restoration projects or offer opportunities for longer-term solutions such as land-use mechanisms and creek ordinances.

4 CONCLUSION

We have reviewed existing literature and freely available datasets to develop a geospatial framework that prioritizes restoration of engineered channels to multi-functional green infrastructure. This framework prioritizes channel reaches, parcels, and watershed area for in-channel, floodplain, and watershed infiltration strategies. It serves as a new tool that can help align community stakeholder interests, policy agendas and planning efforts toward effective implementation of multi-functional green infrastructure and investment in floodplain corridors as community resources that also help meet the watershed's hydrologic and ecological needs. Work remains to be done to quantify the benefits of these restoration projects, potential feedbacks between increased watershed infiltration and stream flow, cost and added value, and the overall potential for ecosystem restoration in constrained urban environments.

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