Memorandum #1
Identifying Benefits and Beneficiaries of Groundwater Recharge from Floodwater Diversion

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For Sustainable Conservation

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OVERVIEW

One design objective for the incentives that are developed in this study is distribute the costs of doing recharge so that they are more equitably shared by those that benefit from the action. [2] In this memo, we identify the main beneficiaries of groundwater recharge and flood risk reduction associated with a program to use floodwater releases to recharge depleted groundwater basins in California's Central Valley. One of the main purposes of compiling this beneficiary information is to inform newly created Groundwater Sustainability Agencies (GSA) of the range of beneficiaries from groundwater recharge. This information may be useful as they design ways of incentivizing groundwater recharge and financing the costs of recharge in their Groundwater Sustainability Plans.

This study explicitly considers a wide range of potential benefits and beneficiaries, including public and indirect benefits such as those to water supply, habitat, downstream communities, and transportation networks. We have employed this comprehensive approach to fully explore the effects of applying the beneficiary-pays principle to incentivizing and financing groundwater recharge. By casting a wide net for beneficiaries, we expect to maximize the number of potential beneficiary/financial mechanism combinations. Designing effective financing mechanisms based on the beneficiary pays principal translates to more capital to support groundwater recharge.

SUMMARY OF POTENTIAL BENEFICIARIES

We define *beneficiaries* as entities that generally own, use, or control assets used for specific *purposes* (i.e., *activities*) that *benefit* from groundwater recharge programs in the Central Valley

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[2] Another important objective is to attract and reward participation by growers in accepting floodwaters to percolate into aquifers. Those considerations are discussed in a separate forthcoming whitepaper.

and surrounding areas.[3] For example, downstream growers (beneficiaries) benefit in two ways: first, through recharge of their aquifers used for irrigating crops, and second, by avoiding flood damages to their fields where they grow those crops (purposes or activities) through protection provided by upstream growers that take floodwaters on their fields for groundwater recharge. We can attach monetary estimates of benefits to purposes or activities through different economic analytic methods, depending on the types of purposes. Some of these purposes are part of individual or private transactions or activities for which economic value can be readily estimated (e.g., buying and selling of agricultural products); other purposes create more broad public benefits for which a value is not easily determined because we cannot observe prices (e.g., public enjoyment of habitat and all of the various concurrent benefits from enjoying species existence).

The various benefits of an on-farm groundwater recharge program can be separated into the direct benefits of groundwater recharge, and the associated co-benefits which cover a range of benefits from flood protection, upstream discharges, and ecosystem improvement. Direct benefits of groundwater *recharge*, as identified in California's Sustainable Groundwater Management Act (SGMA) legislation, include:

> *Increasing groundwater levels, increasing groundwater storage, improving water quality, mitigating land subsidence associated with overdraft, and improvements in water supply to interconnected surface water sources*.

There are also indirect benefits of the program, associated with improved flood protection in the Central Valley and downstream, as well as upstream benefits not directly associated with groundwater. As described in the DWR's *Handbook for Assessing Value of State Flood Management Investments*,[4] categories of benefits of flood protection include:

> *inundation-reduction benefits, intensification and location benefits, agricultural flood risk management benefits, and loss-of-life benefits*.[5]

The 2013 *California Water Plan* also identifies benefits of integrated flood management to include water supply benefits, environmental benefits, water quality benefits, recreation benefits, hydropower benefits, and navigation benefits. In this analysis, we draw on all these sources to identify the set of beneficiaries in the Central Valley.[6]

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[3] Appendix A includes a glossary of key terms used in this report.

[4] California Department of Water Resources. *Handbook for Assessing Value of State Flood Management Investments*. 2014.

[5] "*Inundation reduction* benefits are reduced or modified flood damage, costs, and/or losses, to existing or future economic activity... Improved flood protection can make flood-prone land more suitable for development resulting in intensification and/or location benefits. When the land use is the same without or with a project but the intensity of land use changes, an *intensification benefit* may accrue to the project… When the land use changes between the without-project and with-project conditions because of a new economic use, a *location benefit* may accrue to the project."

[6] Appendix B describes different dimensions of measuring benefits and segmenting beneficiaries. Some of these dimensions are included in further discussion below.

We describe categories of beneficiaries in terms of their geographic location in relation to the site of potential on-farm groundwater recharge projects and the types of benefits received. As described more thoroughly below, proximity to potential project sites is important not only to better understand the relationship between flood protection and the benefits received, but also to determine the feasibility of using specific financing mechanisms.

Geographic Context and Risk Considerations

The benefits of flood protection from groundwater recharge in the Central Valley is affected by the geographic location of the beneficiary. Consequently, this analysis groups beneficiaries by region because the benefits received vary with position along the waterways.

As one example is the most commonly cited example of the benefits of groundwater recharge: neighboring agricultural operations can directly benefit through increased recharge that reduces pumping head for irrigation. The value of that benefit can be in reduced pumping costs, improved groundwater quality, or less reliance on surface water deliveries. These benefits are similar to those realized by conjunctive use projects.

As an example of indirect benefits, upstream beneficiaries such as upstream flood control agencies depend on the ability to discharge floodwater into Central Valley rivers, streams and canals to protect their areas. The value of diverting floodwaters for groundwater recharge to these beneficiaries depends on the costs of alternative floodwater control options and methods of reducing river discharges. These indirect benefits to upstream beneficiaries fundamentally differ from the more direct flood protection benefits received by agricultural operations and landowners in the Valley.

To address these important geographic distinctions, this analysis organizes beneficiaries by geographic region. We also note that Central Valley flood protection may provide benefits to state and national beneficiaries; however, analyzing the value to potential beneficiaries outside of the state is not included in the scope of this study.

This study groups beneficiaries according to the following regions:

- *Local beneficiaries* within the Central Valley include areas overlying the groundwater basin where recharge takes place,
- *Downstream beneficiaries* include growers and localities behind flood levees, instream diverters, and aquatic and terrestrial habitat,
- *Upstream beneficiaries* include dischargers upstream of recharge locations, such as hydropower generation and surface water storage reservoirs, and
- *Statewide and national beneficiaries* include maintenance and improvement of ecosystems, and regional, state and national economies that avoid damages and see increased activity.

These geographic distinctions correlate to some degree with the separations of benefits and beneficiaries by primary/secondary and direct/indirect. Local beneficiaries are more likely to receive direct and primary benefits, while those outside of the targeted aquifer are more likely to be peripheral and secondary. The category of benefits also is likely to vary.

DESCRIPTION OF BENEFICIARIES AND BENEFITS

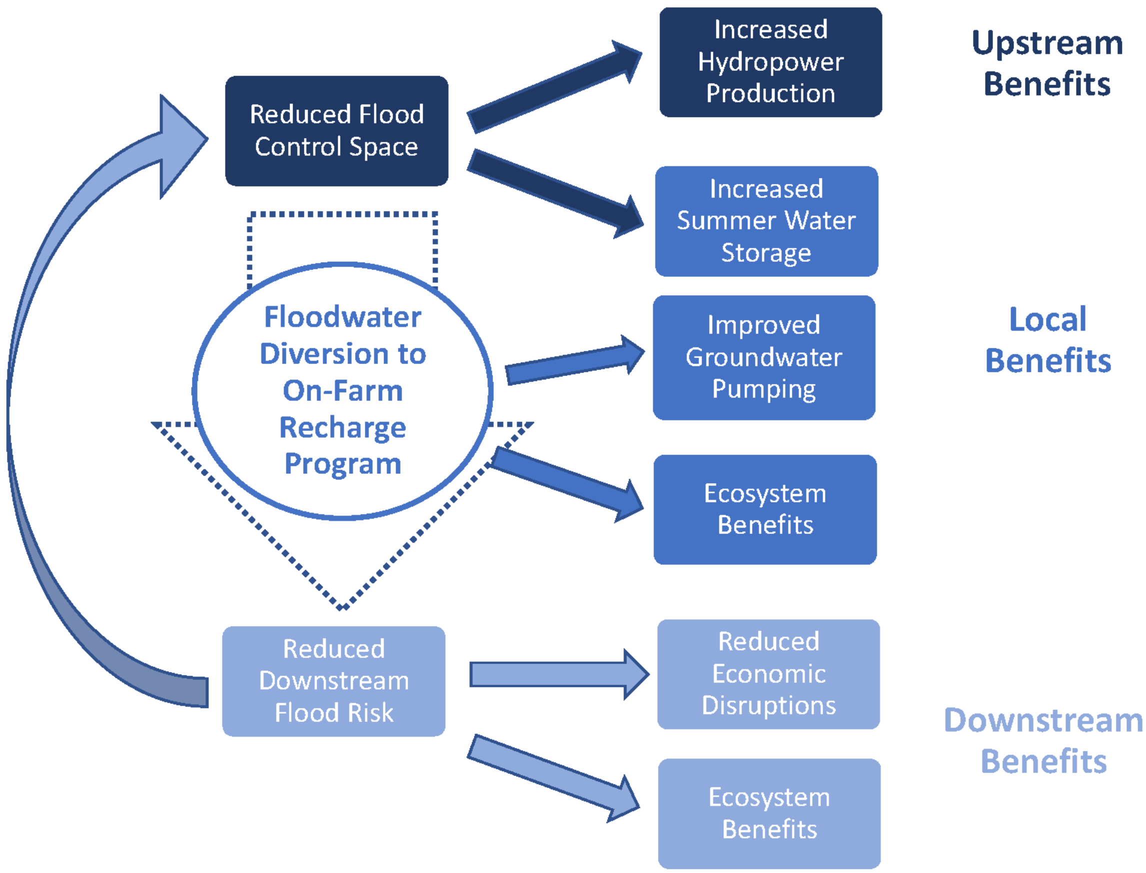
The following section gives a brief explanation of each beneficiary. Conceptually, measures of benefits are commensurate with the economic and social value of the production of goods and services, or of the assets and resources at risk to flooding. The direct benefits of groundwater recharge include increasing groundwater levels and increasing groundwater storage, improving water quality, mitigating land subsidence associated with overdraft, improved instream flows in interconnected surface water sources. Indirect benefits include annual damages avoided by improving flood control from their current level of protection to a target level of protection—both upstream and downstream, increased surface water supplies from upstream storage, and increased and higher value hydropower generation derived from greater reservoir storage. Note that several "benefits" are avoided stressors that would have been incurred by one party due to actions by another party. The most relevant example here is that upstream flood control entities often manage floods by diverting flows downstream to be managed by yet another flood control entity, thus transferring stress to the downstream party. Providing more flood management flexibility can relieve that stress, thus creating a benefit for the upstream entity.

Figure 1 illustrates some of the relationships among different benefits. The figure divides the benefits geographically, and shows where interactions occur, such as between downstream flood risk management and upstream water storage.

Direct benefits, such as improved groundwater pumping and local ecosystem benefits are the primary outcomes from on-farm recharge. Improved groundwater pumping takes place in terms of an increase in groundwater levels and available acre-feet (AF) of sustainable yield, while local ecosystem benefits are evident in the acres of land flooded under programs that provide transitional habitat birds and other species.

Other benefits are more indirectly related. For instance, floodwater diversions to an on-farm recharge program reduces downstream flood risk, measured in terms of acre-feet (AF) of water diverted or the reduction in peak streamflow downstream measured in cubic feet per second (cfs) or floodstage (in feet). In turn, reduced downstream flood risk reduces economic disruptions from flood events, as measured by a reduction in expected annual financial damages associated with the change in flood risk and the accompanying secondary economic impacts. These secondary impacts extend beyond the groundwater basin to the state economy in avoided losses. Reduced flood risk downstream also reduces the need for winter and spring flood control space in upstream reservoirs, increasing the acre-feet of storage space that can be used for other purposes. Water managers can store more water to sell to local and project water users during the dry irrigation season. Hydropower producers can increase the acre-feet of water stored for use in hydropower production, increasing total kilowatt-hours of energy production and the ability to time that generation to provide more megawatts (MW) of reliable peak capacity. Together, the increase in streamflows during the dry season can also benefit local habitat, both in terms of instream, and associated wetlands and riparian habitat. These direct and indirect relationships are summarized in Figure 1.

Fig. 1. Benefit Relationships



Estimating economic benefits is beyond the scope of the current analysis, particularly since those benefits are geographically specific. Benefits can be estimated through several different economic methods including revealed willingness to pay and stated preferences for willingness to accept. In practice, this can be difficult to estimate directly; benefits are often calculated by estimating the cost of alternatives (e.g. the cost of alternative water supplies or the cost of flood damages from incremental flood control improvements) as a proxy for the direct economic value.

Benefits can accrue across an entire district or agency service area, or to individuals. Whether growers and customers reside inside or outside of a district affects the level of benefits that those growers and customers realize. In some cases, trade-offs may arise among private short-term benefits and public sustainability benefits. These issues are often specific to situations and are not explored further here, but should be part of any consideration of an overall benefits assessment.

Table 1, below, presents our initial summary of all entities, whether private or public, that would receive benefits or services (i.e., asset protection, reduced groundwater pumping costs, ecosystem enhancements) from a groundwater recharge and flood protection program. Table 1 also identifies the primary types of benefits that accrue to each category of beneficiaries. We intend this list of beneficiaries to be comprehensive. Many of the beneficiaries receive multiple benefits, but are often a subset of a larger beneficiary group. We distinguish those beneficiaries to keep the trail of benefits clear. For example, agricultural growers may be using both groundwater and surface water, but many are using only one or the other. So, we separate growers who are using groundwater, both solely and conjunctively, from those who rely solely on surface water. The table includes the primary regional relationship within a watershed for each category of beneficiary. The table also identifies direct and primary benefits to specific beneficiaries from indirect or peripheral and secondary benefits.

Table 1. Summary of Beneficiary Categories

Beneficiaries	Mitigated detrimental groundwater impacts					Indirect benefits						
	lowering of GW levels	reduction of GW storage	degraded water quality	land subsidence	depletion of interconnected surface water	increased surface water storage/water delivery	improved surface water supply reliability	Improved soil quality and productivity	intermittent wetland habitat	improved flood control	potential increase in hydropower production	secondary economic benefits
Local Beneficiaries												
Local Agricultural Growers	**X**	**X**	**X**	**X**		**X**	**X**	**X**		**X**		x
Local Municipal Water Providers and Customers	**X**	**X**	**X**	**X**		**X**	**X**			x		x
Local Agricultural Water Providers and Grower Customers	**X**	**X**	**X**	**X**		**X**	**X**				x[a]	x
Rural Residential and Other Private Well Users	**X**	**X**	**X**	x						x		x
Local Ecosystem			**X**		**X**			**X**	**X**			x
Infrastructure Owners and End Users				**X**						**X**		x
Upstream Beneficiaries												
Upstream Flood Protection Agencies										**X**		x
Hydropower Owners and Operators											**X**	x
Surface Water Project Customers						**X**	**X**					x

	Mitigated detrimental groundwater impacts					Indirect benefits						
Beneficiaries	lowering of GW levels	reduction of GW storage	degraded water quality	land subsidence	depletion of interconnected surface water	increased surface water storage/water delivery	improved surface water supply reliability	Improved soil quality and productivity	intermittent wetland habitat	improved flood control	potential increase in hydropower production	secondary economic benefits
Downstream Beneficiaries												
Downstream Commercial and Residential Property Owners	**X**	**X**	**X**	**X**						**X**		x
Downstream Agricultural Operators	**X**	**X**	**X**		**X**	**X**	**X**			**X**		x
Infrastructure Owners and End Users				**X**						**X**		x
Downstream Ecosystem					**X**				**X**	**X**		
State Economy	**X**	**X**		**X**		**X**	**X**	**X**		**X**	**X**	**X**

Notes: [a] – Districts benefit from increased hydropower to the extent that they own portions of the power plants.
A large X denotes a primary or direct benefit; a small x denotes a secondary or peripheral benefit.

Local Beneficiaries

Local Agricultural Growers Relying on Own Water Supplies

Agricultural operators within the groundwater basin benefit directly from groundwater recharge. Increasing groundwater levels will reduce pumping costs for agricultural users that rely on groundwater sources exclusively or for agricultural users that supplement surface water supplies with groundwater in dry years. The program also has the potential indirect benefit of increasing surface water deliveries with increased storage behind dams upstream of the Valley. Both of these benefits have the effect of improving water supply reliability for agricultural operators.

Additional benefits for program participants can be improved soil quality that leads to increased productivity. Using floodwaters for recharge may flush agricultural chemicals and be used to manage soil salts.

Tenants and owner-operators may realize their benefits in different ways. The degree to which benefits accrue to tenants or landowners depends on the time frame in which the benefits occur. Over the long run, landowners will gain more benefits as land values reflect improved aquifer and soil conditions. So, while both benefit from reduced pumping costs, the value of the longer-term increases in aquifer storage are more likely to accrue to land owners through increased rents.[1]

Local Agricultural Water Providers and Customer End-Users

Local agricultural water providers, such as irrigation and water storage districts, and their customers receive numerous benefits. Note that many of these end-users overlap with the local growers discussed previously, but these benefits may flow through in different paths.

Those with groundwater supplies within the target basin benefit directly from groundwater recharge. Increased groundwater levels will reduce pumping costs for local districts. In addition, improving groundwater conditions in the Central Valley will improve water supply reliability for local water agencies that currently rely on increasingly unreliable imported water supplies and overdrafted groundwater basins. Many of these providers manage conjunctive-use projects that can become more efficient as aquifer conditions improve. Using floodwater releases for groundwater recharge will also result in improved water quality in Valley aquifers that currently have a high level of nitrates and salinity due to agricultural runoff.

[1] The literature on energy efficiency shows how improvements in the building envelope and appliances can lead to increased rents and housing values.

A separate set of benefits accrue to local water agencies that rely on surface water supplies. Groundwater recharge not only reduces pressure on surface water supplies due to increased reliability of groundwater for ag and rural pumpers,[2] in some places it also improves surface water supply reliability due to the interconnection between ground and surface water sources. For example, many growers both receive both surface water deliveries from their water purveyors and use groundwater as a back up source for dry years.[3]

Local Municipal Water Providers and Customer End-Users

Residential, commercial, and industrial water users (termed here as "municipal" water users, as distinct from agricultural water users) in the Central Valley rely on a mix of local groundwater, surface water, and imported water for their water supply. Depending on their supply mix, municipal water agencies and water users may receive multiple benefits from a groundwater recharge program akin to those listed for agricultural water agencies. These benefits have real cost savings that will be passed on from the utility to the end user. Providers that rely on groundwater will see reduced groundwater pumping costs, improved water quality, and improved supply reliability. Districts that rely on surface water may also see improved surface water reliability.

A subgroup of municipal water customers is in disadvantaged communities. These are often unincorporated towns served by community service agencies (CSAs) established by the county. These communities tend to rely heavily on aquifers that compete with agricultural operations because they cannot afford the deeper wells that larger towns and cities drill. As a result, these wells run dry more frequently and can be contaminated from agricultural and residential runoff.[4] In addition to naturally-occurring mineral elements, for over 100 years agriculture has been applying nutrients and other additives that can leach through soils into groundwater when over-applied. Despite improvements in farming practices and technologies made today, improvements in groundwater quality are difficult to detect due to the lingering effects of legacy concentrations in the soil and groundwater below.

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[2] The original intent of the Central Valley Project as it was approved in 1940 was to reduce groundwater overdraft in the San Joaquin Valley. As overdraft is relieved in other ways, demand for surface supplies may be relieved as groundwater can be substituted for imported surface water. (California Department of Water Resources, "History Of The California State Water Project," http://www.water.ca.gov/swp/history.cfm.

[3] With the increased use of microdrip and subsurface irrigation systems, some growers are switching to groundwater during certain irrigation periods because groundwater tends to have less particles in it that can clog these irrigation systems.

[4] State Water Resources Control Board, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water, AB 2222 Report to the Legislature," http://www.swrcb.ca.gov/gama/ab2222/docs/ab2222.pdf, January 2013.

Rural Residential and Other Private Well Users

In addition to local municipal and agricultural groundwater users, there may be other rural residential or small commercial beneficiaries that depend on private wells in the Central Valley that receive similar benefits from increased grounding groundwater levels. These individual users tend to have shallower wells connected to the aquifer being used by farm operations. Their benefits will accrue in a similar manner as the smaller CSAs.

Disadvantaged individual residents are more likely to rely on wells that are at higher risk than other municipal users, but those residents are less likely to be able to afford drilling deeper or bringing in alternative water supplies.

Local Ecosystem

The local ecosystem, composed of the physical habitat and community of related species in the Central Valley, have the potential to benefit directly from increased instream flows in places where there is interconnectedness of groundwater and surface water sources. It also benefits indirectly from an on-farm groundwater recharge program that uses on-farm flooding as the recharge mechanism. On-farm flooding provides periodic intermittent wetland habitat, particularly for migratory bird species. Further, reduced need for downstream levees can benefit the terrestrial habitat by reducing levee footprints. This enhances the ability to manage floodplains for multiple benefits including improved habitats.

Downstream Beneficiaries

Downstream Residential and Commercial Property Owners

The residential and commercial beneficiary category includes downstream Central Valley and Delta residents and local business owners who own private residential and commercial structures and property. This property would be directly damaged by flooding from floodwaters in the basin, and owners benefit from avoiding these losses through improved flood control.

Downstream Agricultural Operators

Owners of agricultural land downstream of project areas, including those in the Delta, also benefit from improved flood control in the Central Valley. This property would be directly damaged by flooding in the Central Valley, and owners benefit from avoiding these losses through improved flood control.

Infrastructure Owners and End-Users

The Central Valley and the Delta, given their location at the center of the Northern California megaregion, serve as an infrastructure hub for the movement of goods, natural resources, and people across Northern and Central California, the state, and beyond. Owners of multiple types of physical infrastructure assets benefit directly from flood protection in the Central Valley. Owners of these physical infrastructure assets and end users benefit from improved flood protection in the form of service reliability and avoided infrastructure downtime. The loss of product or service revenues is potentially a larger consequence to infrastructure owners than the direct loss of the physical infrastructure. Infrastructure in the Central Valley and downstream in the Delta include oil and gas pipelines, railroads, electricity transmission, and highways.

Downstream Ecosystem

Downstream ecosystems also benefit indirectly from flood control improvements offered by a groundwater recharge program perform many complex and interrelated functions that not only provide basic biological support but also valuable goods and services to society.[5] In the case of the Central Valley, these could include floodplain and wetlands impacts in the Sacramento-San Joaquin Delta, including flood conveyance and storage, erosion control, pollution prevention and control, fisheries, water supply, recreation, food production, education and research, historical and archaeological values, open space and aesthetic values, and habitat for waterfowl and other wildlife, including game species.

Upstream Beneficiaries

Upstream Flood Protection Agencies and Dischargers

Upstream beneficiaries include flood control agencies and protected properties along those waterways that flow to the targeted basin. Upstream flood management agencies and dischargers are able to avoid flooding downstream due to the improved flood control provided by the downstream groundwater recharge program through flood flow diversion.[6] These dischargers can avoid the cost of alternative diversion, storage, treatment and discharge methods by discharging floodwaters into public waterways. This beneficiary category includes new upstream development. Importantly, increased channel capacity through flow diversion that reduces downstream flood risk can allow flood control managers, including the Army Corps of Engineers, Central Valley Project and local dam operators to reoperate their reservoirs so as to reduce the

[5] See Chapter 4 "Ecosystem Valuation Methods" of DWR's *Economic Analysis Guidebook* (2008) for further discussion of this issue.

[6] Downstream flood risk is the driving parameter for decisions on upstream flood control management. If the risk is reduced by diverting flows downstream, that should change the flood control parameters. Being able to flood agricultural fields is the same as an increase in the flood flow capacity of the leveed channels. This premise is the basis of the Sacramento flood control scheme with its multiple bypasses. See for example, MBK Engineers, "System Reoperation Study Forecast-Based Operations Analysis," Draft Technical Report Prepared for the Department of Water Resources, Sacramento, California, http://www.water.ca.gov/system_reop/docs/Attachment%20A%20-%20Feb%202014%20Draft%20System%20Reoperation%20Study%20Forecast-Based%20Operations%20Analysis.pdf, February 2014.

amount of flood-control space during the winter months. This leads to increase stored water during the summer. These benefits are not often considered in past beneficiary studies of flood control or groundwater recharge projects.

Hydropower Owners, Operators and Electric Utility Customers

Many large hydropower facilities are co-located with multi-purpose flood control and water storage reservoirs. Optimizing flood control operations provides more water management flexibility to achieve multiple benefits including improved storage and hydropower generation. Increasing flood water storage space directly trades off with storage for water supplies and summertime hydropower generation. Being able to accommodate greater flood flows in the Central Valley through a groundwater recharge program reduces the need for flood storage and increases reservoir storage. That added storage can increase the power generated during the more valuable summer peak load season. That will both reduced electricity bills and emissions from other power plants that are displaced by the hydropower.[7]

Surface Water Project Customers

Customers of surface water projects in the San Joaquin Valley that are used both for surface water storage and flood control will see water supply benefits under a groundwater recharge program. This includes CVP customers, such as those on the Friant-Kern Canal, as well as those that rely on Army Corps of Engineers (US ACE) projects on the east side of the San Joaquin Valley such as Terminus Dam and Success Dam in the Tulare Basin, and local projects such as New Don Pedro Dam operated by Modesto Irrigation District and Turlock Irrigation District. Increasing flood releases as part of a groundwater recharge project increases reservoir water supply storage space. Customers of these projects that do not already fall into one of the local water supply beneficiary categories gain greater water supply reliability.[8]

Regional and State Economies

Economic impacts of a groundwater recharge program in the Central Valley can spread beyond the entities that receive direct and indirect benefits. For example, local agricultural producers that see decreased groundwater pumping costs due to a groundwater recharge program may use those savings at local agricultural equipment dealers. For indirect benefits, flooding of a single Delta island impacts not only the property owners on that island, but also business owners on neighboring islands that may depend on agricultural inputs or outputs from the flooded island. Agricultural

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[7] See Appendix C, "How Hydropower Benefits from Floodwater Recharge," for more detail.

[8] Whether these customers are included in the relevant GSA will be a key distinction in determining benefits and expected contributions.

examples of who is likely to receive these benefits include equipment and fertilizer dealers for inputs, or trucking and packing houses for outputs, however, these benefits will occur throughout the local economy. Changes in local economic activity from upstream or downstream economic transactions are termed secondary impacts. The state economy is a highly-interrelated system, where impacts do not occur in isolation. This beneficiary category accounts for the owners of businesses located in the state that receive secondary benefits from improved water supply and flood protection conditions in the Central Valley

APPENDIX A BENEFICIARY ASSESSMENT TERMS AND DEFINITIONS

Relevant Terms for the Beneficiary Assessment	Definition [Source Code]
benefits	
economic benefits	Economic benefits are a measure of the willingness to pay for goods and services derived from implementation of a program or project—benefits could be measured in terms of the value added to an entity or person, or in the value of costs or damages avoided. [2, as modified]
private benefits	Benefits that accrue to identifiable subset of the community and from which individuals can be excluded. The ability to restrict benefits to those that pay enables these benefits to be funded with user money. Note that as used here, private beneficiaries would include "public" agencies that provide services to an identifiable group of users [2]
public benefits	Benefits that are shared by a wide cross-section of the community and from which individuals cannot realistically be excluded. Inability to exclude individuals means that imposing charges for access to the benefit is difficult. If 'free riders' can access the benefits without paying, there is no economic incentive for them to spend their money for these benefits. This means that if these benefits are to be created, public funding must usually be used. [2]
local benefits	For purposes of this assessment, local benefits are defined as those benefits accruing to landowners within the boundaries of the Legal Delta.
beneficiary	Any entity (individual, group, organization, agency, or community) that receives benefits or services (i.e., asset protection, protection from water supply disruption, or ecosystem enhancements) from the existing Delta levee system, or that would receive benefits or services from future investments in the Delta levee system. [1]
direct beneficiaries	Direct beneficiaries are those whose property or assets are affected in the case of avoiding or minimizing flooding [1]
indirect beneficiaries	Indirect beneficiaries are those who are affected from secondary effects of flooding, such as reduced access to shipped products if a highway is damaged. [1]
assets	
assets	For purposes of this assessment, an asset is defined as property owned by a person or group—or any item that can be considered for the common good—that is regarded as having economic value. [1]
tangible assets	Tangible assets are physical assets, such as land, vehicles, equipment, and machinery. Tangible assets are at risk of damage, either from naturally occurring incidents, or by accidents. Tangible assets, sometimes referred to as tangible fixed assets or long-lived tangible assets, are divided into three main types: property, plant, and equipment. [7, as modified]
intangible assets	Intangible assets are nonphysical. Depending on the type of entity that owns them, intangible assets may include permits, licensing agreements, and service contracts, among others. Intangible assets can add value to an entity's future worth. In some cases, intangible assets can be much more valuable than tangible assets. [7, as modified]
cost allocation	

Relevant Terms for the Beneficiary Assessment	Definition [Source Code]
cost allocation	Cost allocation refers to methods that can be used to allocate the costs of a program or project to different beneficiaries. The particular method that is used to allocate costs often depends on the data that are available because each method has different data requirements, and the allocation typically depends on the underlying assumptions on which the allocation is to be based. The method also is dependent on the legal requirements specified in particular financing mechanisms. For example, in project levees the cost allocation methodology is specified in federal and state law. For local funding, whether revenues are derived from assessments or special taxes can determine the cost allocation method which can differ from federal law. Cost allocation is the process by which financial costs of a project are distributed equitably among project purposes. A common cost-allocation method is Separable Costs-Remaining Benefits (SCRB) which distributes costs among the project purposes by identifying separate costs and allocating joint costs or joint savings in proportion to each purpose's remaining benefits.[4]
separable costs	Separable costs are project cost savings with one purpose excluded, or costs incurred for structures serving multiple (but not all) purposes. In some cases, specific and separable costs, which are costs of facilities serving only one included purpose, are the same. [6]
non-separable costs	Non-separable costs, also known as joint or residual costs, are costs of features that support all included purposes plus otherwise unallocated costs (e.g., environmental, aesthetic, and social). [6]

Notes:

[1] Delta Stewardship Council. Delta Levee Investment Strategy: Technical Memorandum 2.1: Baseline Information on Islands and Tracts, Assets, Hazards, and Beneficiaries. 2015.

[2] CALFED. CALFED Bay-Delta Program Draft Implementation Plan: Financing Plan. 2005

[3] Delta Protection Commission. Economic Sustainability Plan for the Sacramento-San Joaquin Delta. 2012

[4] Department of Water Resources. Economic Analysis Guidebook. 2008

[5] Delta Stewardship Council. The Delta Plan. 2013

[6] Delta Stewardship Council. Delta Levees Investment Strategy. Technical Memorandum 3.2: Cost Allocation Methodology. April 15, 2015.

APPENDIX B THE MANY TYPES OF BENEFICIARIES AND BENEFITS

Groundwater recharge and flood protection benefits to beneficiaries can be differentiated and categorized in many ways, depending on program purpose or the types of actions subject to a benefits analysis. We use these categories as a means to capture all of the potential beneficiaries of a program to use floodwaters in the Central Valley for groundwater recharge and their relationships. In this study, we adopt the DWR's[1] typology to characterize important categories of benefits, as follows:

- ***Direct and indirect.*** *Direct* benefits are primary benefits realized in the immediate locality of the program due to groundwater recharge. *Indirect* benefits are benefits affecting upstream or downstream areas associated with non-groundwater related benefits such as flood protection or upstream diversions. Hydropower benefits and downstream flood protection benefits are examples of indirect benefits. The benefits listed in the Sustainable Groundwater Management Act (SGMA) are direct benefits; we expand the list of indirect benefits here.
- ***Primary and secondary benefits –*** *Primary benefits* are the increased value of goods and services to beneficiaries immediately affected by a groundwater recharge or flood control project or program. Benefit categories include flood risk management, water supply, water quality, and recreation. *Secondary benefits* are the values of goods and services that subsequently accrue to other parties (beneficiaries) that interact with the primary beneficiaries. Secondary benefits can include changes in economic activity (e.g., regional or state-level jobs and income) and fiscal effects, such as taxes or other revenues, that are important to local stakeholders.[2] Secondary beneficiaries are identified in Table 1, below; otherwise, beneficiaries are considered to be primary.
- ***Private and public goods realized as benefits***[3] – "Goods" are commodities or services that can be used to satisfy human wants and that have exchange value. Characteristics of *public goods* are non-excludability (i.e., it is not possible to exclude non-payers from consuming the good) and non-rivalry in consumption (i.e., consumption of a good by one consumer does not diminish the benefit to other consumers). If a "good" does not

[1] California Department of Water Resources. *Economic Analysis Guidebook*. January 2008.

[2] This typology follows regional economic input-output analysis. In that framework, *direct* effects arise from immediate economic activity, *indirect* effects derive from transactions with directly-affected parties, and *induced* effects are more broad, general economy-wide impacts from changes in direct and indirect activity.

[3] The term "public" as used herein means that benefits (or costs) cannot be easily assigned to specific individuals or entities. Importantly, our use of the term does *not* refer to publicly owned enterprises such as municipal water agencies or utility districts—those are considered "private" entities because the benefits can be assigned to specific individuals who privately enjoy them. In other words, the term "public" is defined within the context of an economic understanding rather than as used in common parlance.

have both of these characteristics, it is considered a *private good*. Goods can fall across the spectrum of this definition; for example, fishing in a river can diminish the availability of the fish to others, but it can be difficult to restrict access to the fishery. This myriad of goods confers benefits on beneficiaries who use them.

- ***Tangible and intangible benefits*** – *Tangible benefits* can be quantified in monetary or other quantifiable units (such as acres of habitat improved), whereas *intangible benefits* cannot be directly expressed in quantifiable terms or metrics (for example, trauma or reduced peace of mind resulting from a flood event).

APPENDIX C: HOW HYDROPOWER BENEFITS FROM FLOODWATER RECHARGE

Many California watersheds have both large river flows and large amounts of storage, giving considerable ability to control levels of generation and water release on a seasonal as well as daily basis. Besides permitting winter-spring runoff to be stored for use in the summer, the considerable storage in various reservoirs can be used to coordinate generation with high electricity load (high market price) periods on a daily and hourly basis. During off-peak hours with low market prices, storable water flows used for hydro generation are reduced, usually to minimum levels, to preserve water for release during high load periods. When water is used to generate above minimum levels during off-peak periods, this is generally because so much water is available that the most economic option is to use some of it for generation even during off-peak hours.

Large storage reservoirs are filled and drawn down on a seasonal basis. A reservoir that supplies water directly to the conveyance facilities leading to powerhouses is called a "forebay." Many powerhouses also have "afterbay" reservoirs downstream of the tailrace. Afterbays serve to smooth out rapid changes in discharge flow and dampen surges in stream flows that could endanger people or damage environmental resources. In many cases, the afterbay of one powerhouse is also the forebay for the next powerhouse in a series of reservoirs and powerhouses along a stream.

Keeping the State's Electricity System in Balance

Operation of a large electric power grid requires several "ancillary services" from generators in addition to basic energy production. In a large interconnected system such as supplies most of California, the load is constantly changing throughout the day as loads at factories, commercial buildings, farms, and homes are turned on and off at various times. In addition, generators are coming on line, changing output and going off line at various times for various reasons. But despite the complexity of the integrated system, one simple operating rule prevails: Generation output must match the load at all times since there is no reserve storage of electricity in the system. Therefore, adjustment of the total generator output to match the load demand is a continuous process. If the system load is greater than the generation, voltage starts dropping and the system loses speed. If the generators pump more energy into the system than the loads demand, the voltage and the speed of the system will increase. These changes are normally very small for a well operated system and go unnoticed. Daily variances in system speed might put electric clocks a few seconds off at the end of the day. That error is corrected by running the system slightly faster through the night. Provision of generation capability to match system output to load is generally referred to as "ancillary services."

California Independent System Operator (CAISO) grid operations involve dispatching generation to meet loads at every point in time, taking into account the physical properties of the transmission grid. The California system accomplishes this task through two instruments. First, the CAISO directly controls substantial generation within its control area that has been placed under Automatic Generation Control (AGC) through awards in the CAISO's Regulation auctions.[4] Second, the ISO operates a real-time balancing-energy auction, which produces both dispatch instructions to change the generation levels of participating resources, and price signals to participants in the informal, price-taking real-time market.

To maintain reliable grid operations, the CAISO must (1) place sufficient (and appropriately located) generation on AGC, and (2) ensure that there is sufficient participation in the real-time markets to meet the likely contingencies. The two tasks are accomplished jointly through the operation of the CAISO's Ancillary Services (A/S) auctions.

The Ancillary Services Markets have been established by the CAISO to ensure that necessary capacity and operational flexibility are available to maintain reliability of the electric system. The PX and, for the most part, the CAISO, procure energy or ancillary services through auctions. There are five Ancillary Services Markets (both day-ahead and hour-ahead) into which energy producers may bid their generation:

- Regulation “up” — generation that is already up and running (synchronized with the power grid) and can be moved via direct electronic commands by the ISO above the unit’s scheduled output level, to keep system-wide energy supply and energy use in balance (Automatic Generation Control [AGC], or market).
- Regulation “down” — generation that is already up and running (synchronized with the power grid) and can be moved via direct electronic commands by the ISO below the unit’s scheduled output level, to keep system-wide energy supply and energy use in balance (AGC, or market).
- Spinning reserves — unloaded online generation that can be dispatched within ten minutes.
- Non-spinning reserves — unloaded offline generation that can be dispatched within ten minutes.
- Replacement reserves — generation that can begin contributing to the grid within an hour.

Utilities generally have an incentive to bid hydroelectric generation into the market in a way that results in the highest value. The characteristics of a particular facility and the amount of water available at a given time may dictate which, if any, ancillary services can be provided. The ability to provide AGC market services (regulation up/down) is subject to having the specific hardware and control systems that enable remote control of output by the CAISO.

[4] Automatic generation control allows a unit’s power level to be altered every four seconds to follow momentary changes in system load. Electricity supply and demand must be balanced every instant within narrow tolerances to prevent system collapse.

Regulation

The CAISO procures enough upward and downward Regulation to respond to real-time disturbances. Capacity selected in the two auctions (one for each direction, up and down) are paid the market-clearing price, which can vary from zone to zone. In addition, the net energy delivered from Regulation action settled at the relevant real-time ex-post price. The CAISO's initial response to a system imbalance is a balancing set of AGC signals to generators providing Regulation.

Reserves

The CAISO sets its purchases of reserves to secure sufficient real-time supplies to both meet expected loads and to provide an adequate margin for unplanned contingencies. Spinning and Non-Spinning requirements are set in accordance with the WECC Minimum Operating Reserve Criteria, to five percent of expected demand (net that met by firm imports) served by hydro resources, and seven percent of net expected demand served by non-hydro resources, or the largest single contingency. At least half of these reserves must be Spinning. Replacement reserves are purchased based on the CAISO's forecasts of unplanned outages and on the expected draw on the real-time market (taking into account the expected output of unscheduled RMR operations and other sources of uninstructed deviations).

The three A/S reserve services are arrayed in decreasing order of quality based on their technical requirements. Spinning Reserves must be provided by generators that are synchronized to the grid; a unit's Spinning Reserve capacity is limited to that which may be delivered within ten minutes of the CAISO's dispatch instruction. Non-spinning Reserves have the same delivery requirement, but need not be provided by generators that are synchronized to the grid. Replacement Reserve capacity is limited to that which may deliver energy within 60 minutes of dispatch.

Providing ancillary services requires operational flexibility and agility to respond quickly to changes in load either up or down, and to come on line and to full load in a very short time. Spinning reserve requires the capability to economically operate a unit at a very low load synchronized on the system ready to crank-up to full power in a matter of minutes. Non-spinning reserve service may require a unit to come from a cold start to full power in a matter of 10 minutes.

Hydropower Is Key to Balancing the Electricity System

Balancing generation and load is a challenge because most thermal power plants operate best at constant loads and do not respond quickly to changes in demand. To increase load, a conventional steam plant must first increase the fuel flow and the size of the fire in the furnace to make additional steam for delivery to the turbine. This takes time, especially for older steam-drum type units that have a lot of thermal inertia due to the greater mass of their components. Nuclear plants are even less responsive and are generally operated base-loaded at full capacity. Frequent changes in loads in thermal plants also increases thermal stresses in the equipment and may lead to more frequent equipment failures. Bringing a thermal plant from a cold start to full load may take several hours. Nuclear plants may take a day or more to bring to full capacity after a cold shutdown.

The new generation of combustion turbine (CT) driven thermal power plants have faster start-up and response times than conventional steam plants and may compete with hydro in the ancillary services market. However, many of these CTs are combined cycle plants coupled with steam turbines for topping cycles. The steam cycles may slow the response time of these units.

Hydroelectric resources have always provided a significant portion of the state's reserve and load-following needs. For example, up to 75 percent of the Northern California spinning reserves market is served by PG&E's hydropower assets. The current market structure also provides opportunities for hydroelectric facilities to sell products and services other than just energy. In the current market, a hydropower owner has the opportunity to bid and schedule its generation into the energy markets, then to bid and schedule any unloaded capacity into the subsequent Ancillary Services Markets and the Imbalance Energy Market run by the CAISO.

Hydro generating units are especially well suited for providing ancillary services because they can change levels of output very rapidly and move from no-load condition to full power in a matter of a very few minutes. There is no warm-up time and changes in load levels do not thermally stress components to cause equipment failures. The proven reliability of hydro assures that the ancillary service needed will be available when called for by the CAISO.