Draft

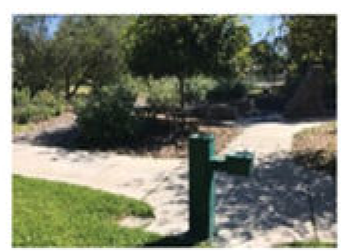
SAN DIEGO STORMWATER CAPTURE AND USE FEASIBILITY STUDY

Modeling Approach and Results Technical Memorandum

Prepared for
County of San Diego

February 2018

Prepared by
ESA
Brown & Caldwell
Burns & McDonnell



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550 West C Street
Suite 750
San Diego, CA 92101
619.719.4200
www.esassoc.com

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SAN DIEGO STORMWATER CAPTURE AND USE FEASIBILITY STUDY

Modeling Approach and Results Technical Submittal

1 Introduction

The San Diego Stormwater Capture and Use Feasibility Study (SWCFS) is designed to provide a regional analysis of the feasibility of planning, constructing, operating, and managing facilities that capture and use stormwater. The goals of the SWCFS include:

- Quantify the range of stormwater that could be potentially captured and stored on public lands and used in the San Diego region;
- Identify the opportunities and constraints for a range of stormwater capture and use examples for use as a management tool in the development and planning of similar projects; and,
- Prioritize the potential stormwater use alternatives on screened public parcels on a short-, mid- and long-term timeline basis.

The quantification goal is achieved by first screening applicable public parcels using a set of criteria that is specific to each stormwater use alternative. This is a more refined analysis than was conducted for the San Diego Region Stormwater Resource Plan (SWRP) (ESA, 2017a) by applying specific parcel screening criteria that accounted for site and technical constraints and modeling more of these sites for specific use alternatives. Eight stormwater use alternatives were identified during methods development.

Example stormwater capture and use projects were analyzed for opportunities and constraints. The project examples were obtained from existing SWRP and Integrated Regional Watershed Management Plan (IRWMP) project lists and input from the SWCFS Technical Advisory Committee (TAC). These examples were developed to provide a tool for managers to evaluate what types of projects may be feasible for a parcel that is under consideration for a stormwater capture and reuse project. Informed by the parcel analysis, managers may use both the parcel analysis and the example projects to conduct a project specific and more detailed assessment of the opportunities and constraints for each individual parcel at a project-level, even if the parcel was not identified in this study. The example projects can also inform the managers determining of the appropriate type of project.

Prioritization will identify the short-term potential use alternatives that have fewer constraints to implementation. These short-term opportunities provide for potential regional planning for these types of projects. Through this analysis, regional constraints to implementing stormwater capture and use will be identified. The SWCFS can be a tool to guide the region over time to address those constraints that can be overcome, such as regulatory constraints and clarity. Overcoming these constraints or "gates" will allow some of short and potentially mid-term projects and alternatives to move forward towards implementation.

In coordination with the TAC, the County of San Diego is developing the SWCFS through a multi-step process. The first step was an extensive data collection effort, documented in first technical memorandum (ESA 2017b). Next, the methods to quantify the potential stormwater capture and use and identify potential projects opportunities and constraints were developed and documented in the second technical memorandum (ESA 2017c). This report summarizes the methods and presents the results of the modeling analysis. The next step will be the development of conceptual-level costs for the example projects and public parcel alternatives. The final step will be the prioritization of the public parcel alternatives for the region.

Section 1 of this report presents an introduction to the conceptual model of stormwater capture and use, as well as a discussion of what makes the San Diego region unique for this study. Section 2 provides the methods used for this modeling effort, Section 3 provides the example projects, and Section 4 presents the results.

1.1 Conceptual Model of Stormwater Capture and Use

The SWCFS is based on a framework that considers each step of the stormwater capture and use process. **Figure 1** presents the conceptual model, which starts with stormwater collection and distribution to a retention or storage site/facility. Because stormwater is delivered in variable and sometimes large volumes during a short timeframe, stormwater collection and storage is needed prior to distribution to use. Depending on the stormwater use alternative identified, stormwater may need to be treated, which requires distribution to a treatment system. Lastly, the treated stormwater needs to be distributed to the end user. The following sections provides more detail on this framework.

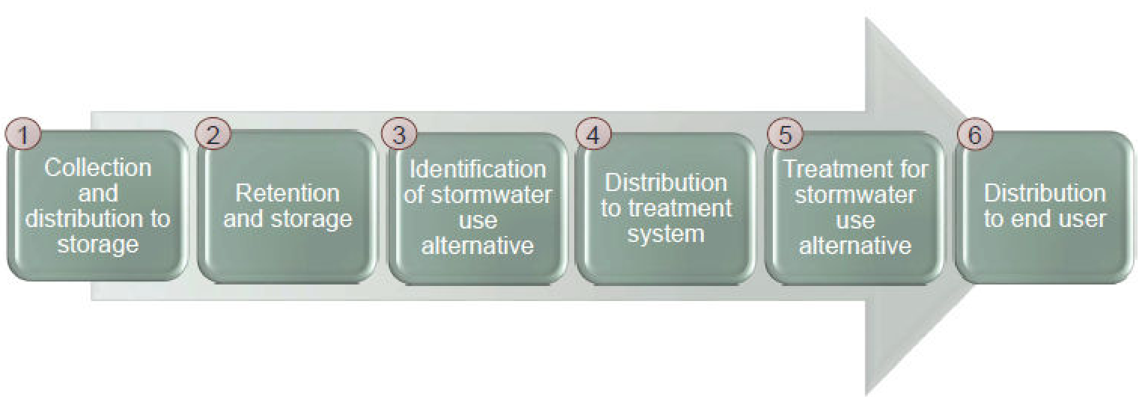

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Figure 1
Conceptual Model

1.1.1 Collection and Distribution to Storage

Stormwater runoff is generated when the demand for water is lowest, as shown conceptually in **Figure 2** for irrigation. Other potential uses are also characterized by this challenge of matching stormwater delivery with demand for its use. For example, conveyance of stormwater for advanced treatment using existing sanitary sewer lines is constrained during storm events, since increased infiltration to the system results in reduced sewer line capacity. Additionally, subsurface soils may limit the rate of stormwater infiltration to recharge groundwater basins and restore natural hydrology. This challenge of matching stormwater runoff generation with when and at what rate stormwater can be used is addressed through temporary storage or "equalization" of stormwater delivery with use.

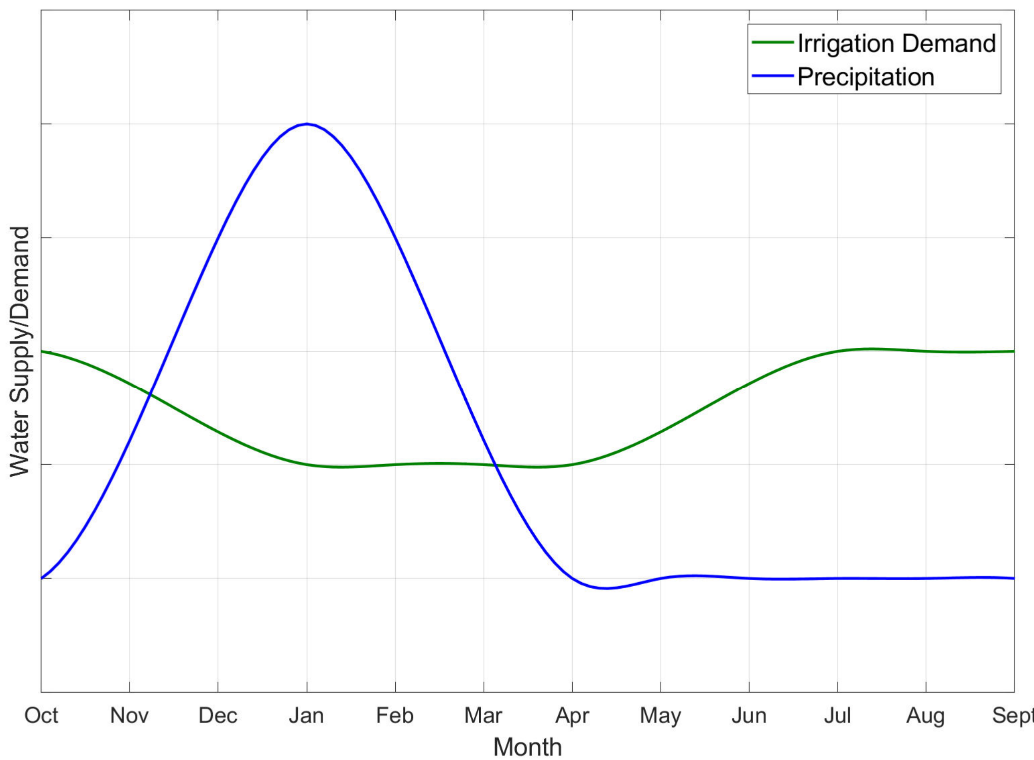

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Figure 2
Conceptual Irrigation Demand and Average Rainfall in Southern California

1.1.2 Retention and Storage

Where to retain and store stormwater is an important element of the conceptual model. The volume of stormwater generated per area is much greater in urbanized areas due to larger areas of impervious surfaces, compared to undeveloped areas (see **Figure 3**). Infrastructure in these urban areas are designed to efficiently direct these larger runoff volumes to storm drain systems to address potential flooding and public safety concerns. Storage of stormwater in these urbanized areas is often limited; however, current new- and re-development regulations encourage the use of low impact development (LID) (see **Figure 4**) to increase retention time of stormwater and allow for filtration and infiltration to reduce the impacts of pollutants and peak flows on receiving waters. These approaches provide opportunities for greater storage.

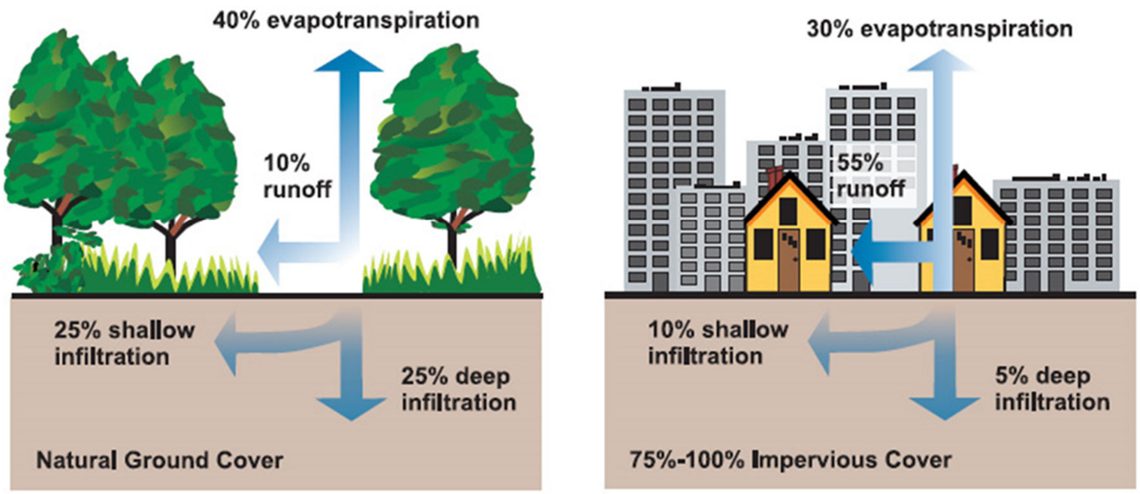

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Figure 3
Runoff as a Percentage of Rainfall
Undeveloped vs. Urban

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Figure 4
Example of LID

1.1.3 Identification of Stormwater Use Alternatives

The third component of the conceptual model is the identification of potential stormwater use alternatives. Eight alternatives have been identified for the region as end uses for stormwater that is captured, and include hydrologic recharge, recycled or potable use, o stormwater treatment. The stormwater use alternatives that will be evaluated for the San Diego region are presented in more detail in Section 2.3.

1.1.4 Treatment for Stormwater Use

Urban stormwater runoff collects and transports numerous constituents from roadways, landscaped areas, and various commercial, industrial, and residential land uses and activities. These constituents include indicator bacteria, metals, pesticides, sediment, nutrients and trash, among others[1]. Treatment to address these constituents would be required prior to some uses, depending on the end use and established water quality standards, treatment facility requirements, and quality of the stormwater captured.

1.1.5 Distribution to End User

The final distribution of stormwater to the end user would depend on the use alternative (or alternatives, for multiple benefits) chosen. This could be directing the stored stormwater to a groundwater basin; to a pre-treatment facility prior to use on-site for irrigation or for groundwater recharge, or to a sanitary sewer line for advanced treatment.

1.2 San Diego Regional Setting

The San Diego region is unique when compared to many other areas in the state in its geology, topography, and micro-climates. The San Diego region has been successful in capturing stormwater in the upper portions of the watershed near the inland mountains where higher rainfalls are captured and stored in reservoirs used for water supply. This system of reservoirs and treatment facilities is shown in **Figure 5**. The volume of stormwater captured in reservoirs represents a limited percentage of the total stormwater that could be captured and used.

San Diego County is dominated by canyon lands with developed mesas that drain to often steep sloped and narrow canyons. Soils in the region are predominately low permeability clays and silts. Isolated groundwater basins are found along the larger river systems and in several inland valleys. The opportunity for direct infiltration to groundwater basis is therefore limited in this region compared to Los Angeles, which has a large groundwater basin with higher permeable soils that extend to coastal urbanized areas. In San Diego, more urbanized areas dominate the coastal areas where a high percentage of the developed land is impervious and urban runoff is directed to the Municipal Separate Storm Sewer System (MS4) to address flood risk and potential property damage and public safety, and directed to flood channels that discharge to estuaries and the ocean.

Because of the geographic distribution of the system of reservoirs in the region, the opportunity for future stormwater capture for one or more of the use alternatives is likely to come from the more-urbanized, western portions of the watersheds, where capture and use is not already implemented effectively. In addition, urban areas have a larger runoff percentage for a given rainfall area (Figure 3), and multiple benefits can be achieved by addressing water quality, flood risk, and community and environmental benefits. New and redevelopment along with targeted retro-fits (e.g. green streets) are using low impact development that increase the retention and

[1] The Clean Water Act Section 303(d) list is available at https://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml

infiltration, where possible, in these urban areas to improve water quality, decrease flood risk, and increase subsurface infiltration to restore natural hydrology.

While this study focuses on existing public parcels, recent and planned expansion of existing reservoirs may offer an opportunity to move storage capacity between reservoirs, providing the potential for greater stormwater collection and storage in existing reservoirs close to urban areas.

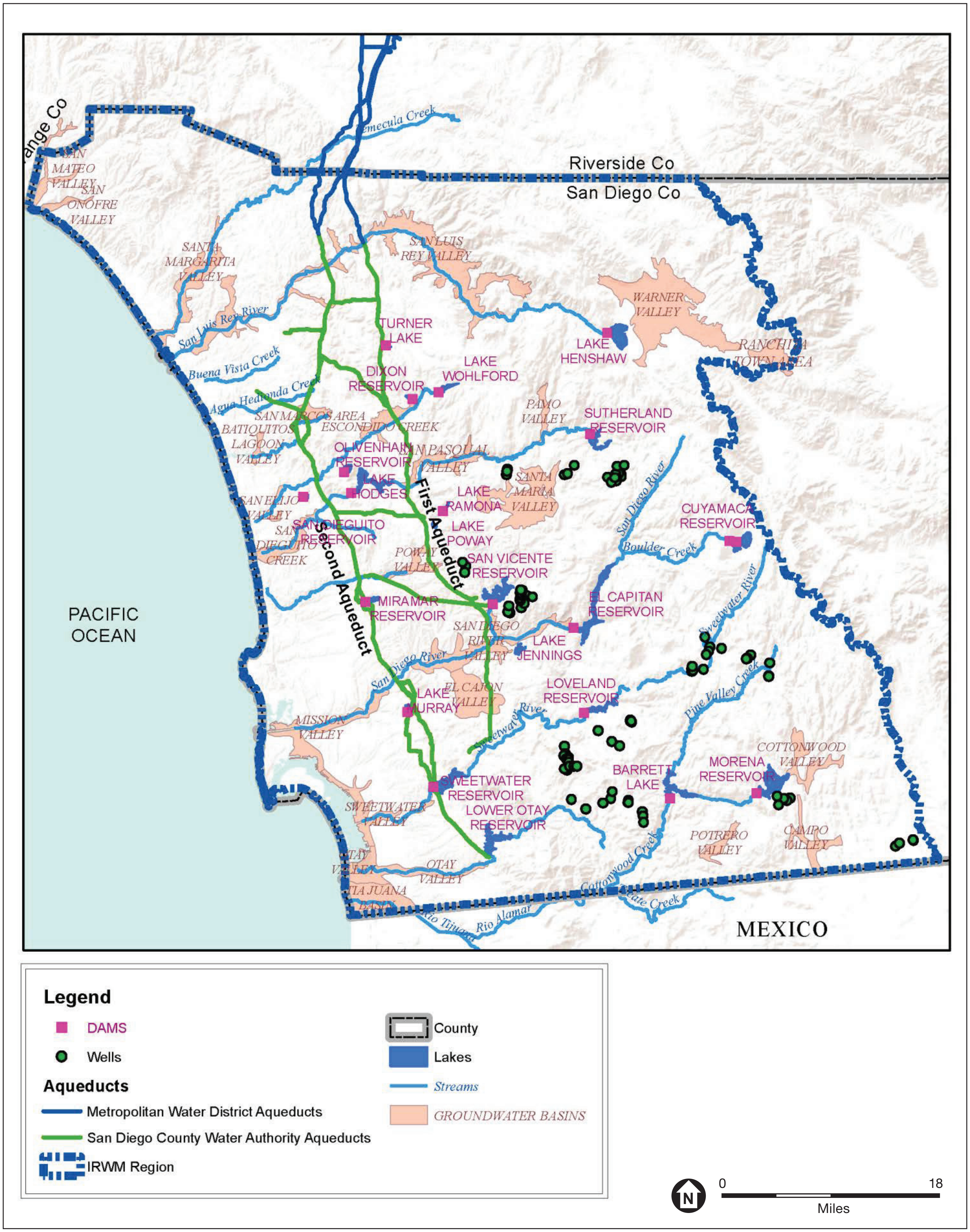
1.3 San Diego Region Stormwater Resource Plan

This assessment builds on the preliminary quantification of potential stormwater capture that was assessed in the SWRP (ESA, 2017a). Potential storage sites were first identified in the SWRP using Geographic Information System (GIS) data for public parcels within the San Diego County region that were designated as open space, park, or vacant, and were at least an acre in size. These public parcels were then assessed for potential stormwater use alternatives that included direct infiltration, storage and off-site use for irrigation, and storage and diversion to a treatment facility for recycled or indirect potable water. The volume estimates were based on a limited number of "conceptual" alternative use project layouts that were then used to project volumes for other parcels. These preliminary estimates did not consider specific site and use constraints for the treatment use alternative, such as location and capacity of existing conveyance lines and treatment facilities. The resulting preliminary *conceptual* total stormwater use potential was approximately 92,000 acre-feet per year (ac-ft/yr). For reference, the San Diego region's annual potable water demand is on the order of 450,000 ac-ft/yr, so this *conceptual* estimate represented about 20% of total regional demand. This preliminary estimate is refined as part of the quantification modeling performed for this feasibility study and the results presented in the following sections.

1.4 San Diego Region Stormwater Capture and Use Feasibility Study

The analysis methodology for this SWCFS is based on the six components of the conceptual model in Figure 1. As presented in **Figure 6,** the SWCFS approach, consists of eight steps. These steps are discussed in more detail in Section 2. The potential public storage sites analysis from the SWRP was refined using screening criteria to determine applicability and feasibility for a greater number of potential stormwater use alternatives. Regional quantities of potential stormwater capture and use are also refined using a significantly larger set of sites for hydrology modeling of storage capacity and conceptual use. Example stormwater capture and use project are also identified and assessed in this SWCFS and provide guidance to managers developing, planning, and designing these projects. These example projects also inform the calculations of the regional stormwater use quantities.

As part of the next step, the use alternatives will be prioritized based on a set of criteria, including total potential regional volume captured and used, cost per volume, constraints and opportunities, and potential multi-benefits. Section 2 describes each step of the model approach and provides examples as a guide.



SOURCE: City of San Diego Basin Study, 2017

SWCUFS

Figure 5
Surface Water Reservoirs and Groundwater Basins in the San Diego Region

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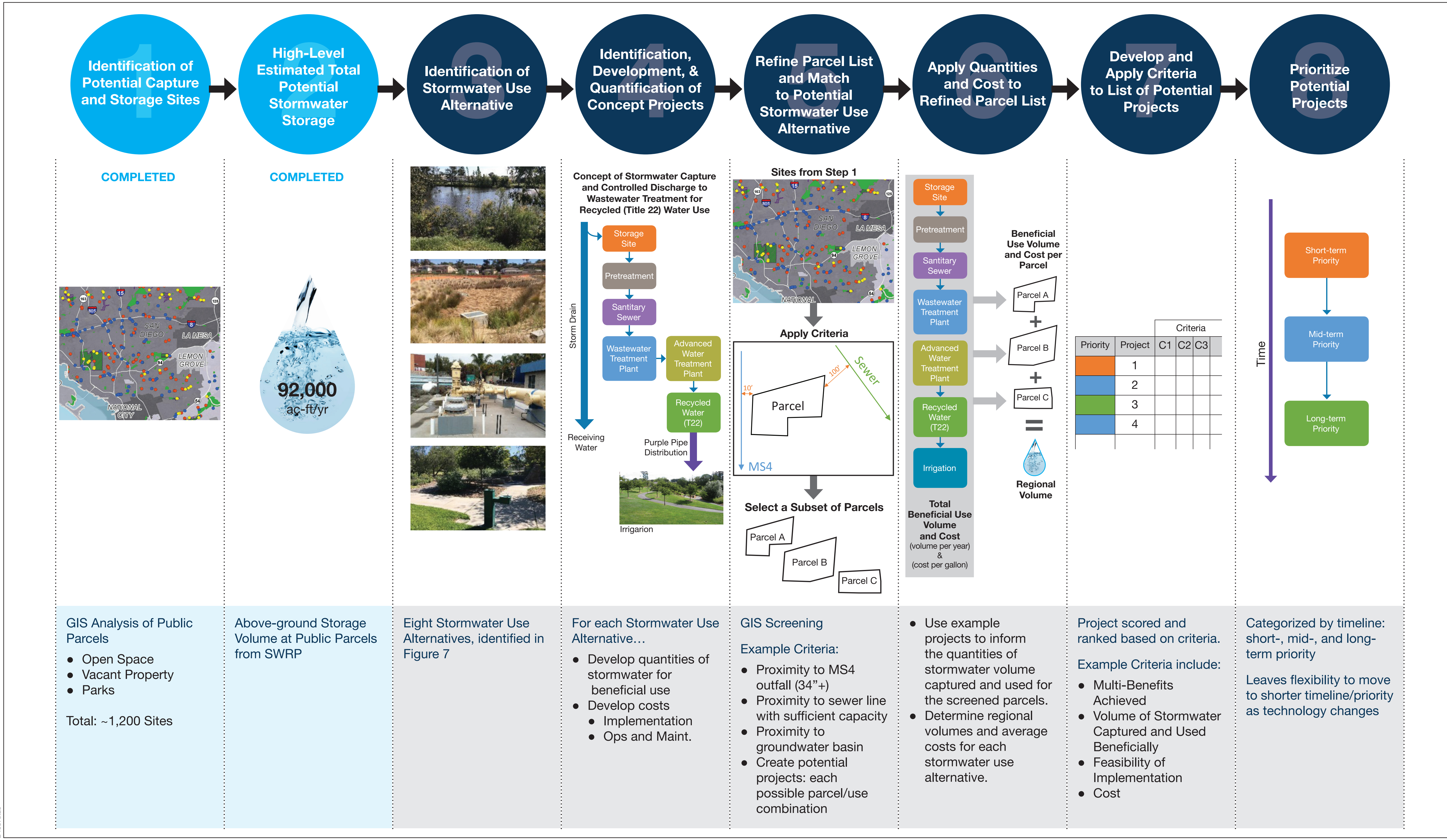

SOURCE: ESA, 2018

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Figure 6
Model Approach

ESA

2 Methods

2.1 Step 1. Identification of Potential Capture and Use Storage Sites

The first step of this SWCFS was initiated as part of the development of the SWRP, and identified potential capture and storage sites on public lands (ESA 2017a). Of the 12,731 public parcels in the region, the SWRP identified approximately 1,200 feasible parcels for stormwater capture, storage, and use. The SWRP analysis considered use alternatives of on-site infiltration to shallow groundwater, use off-site for irrigation, and diversion to a treatment facility for recycled or potable water. The following assumptions led to identification of the applicable parcels, all of which were also greater than 1 acre with less than a 15% slope:

- **Irrigation** – public parcels with a major MS4 outfall (greater than 36 inches (in)) that are within a quarter mile of a park or a golf course.
- **Groundwater Aquifer Recharge –** public parcels within a mile of a groundwater basin that is used for potable water supply.
- **Treatment Facility for Recycled and Potable Water –** assumed excess stormwater from parcels identified for irrigation and groundwater aquifer recharge could be sent to a treatment facility. *There was no refined assessment of the feasibility of this use alternative performed at this conceptual level* (e.g. the location and capacity of existing conveyance lines or treatment facilities).

Next, based on land use criteria, 920 of the original 1,200 parcels were further analyzed and quantified (ESA 2017a). The quantifications conducted for the SWRP were preliminary and conceptual focusing on only three of the stormwater use alternatives. The volume estimates were based on a very limited number of “conceptual” alternative use project layouts that were then used to project volumes for other parcels. These preliminary estimates did not consider specific site and use constraints, such as location and capacity of existing conveyance lines and treatment facilities. The parcel analysis was refined for this study as part of Step 5 (Section 2.6), and the added criteria reduced the available parcels to 211 – 977 depending on assumptions (Section 4).

While stormwater can be captured on both private and public lands, this study and the SWRP focus on public lands. The refined quantification of potential regional stormwater capture and use, and prioritization of example projects and parcel use alternatives are also focused on public lands. Private residential and commercial properties provide a tremendous opportunity for additional stormwater capture and use, and this SWCFS provides management tools for private property owners and managers that are considering or planning stormwater capture and use projects. Example projects such as on-site stormwater capture via rain barrels and cisterns for on-site irrigation and larger capture and use projects for new and re-development are highlighted in this report. These example project provide an assessment of project specific opportunities and constraints that can be used when evaluating and planning stormwater capture and use projects on private sites. The identification and prioritization of opportunities for stormwater capture and use at private sites will be at the discretion of the site owners and managers. Collaboration between public and private partners to develop these projects is encouraged, and these potential opportunities will be discussed in the Final SWCFS.

2.2 Step 2. High-Level Estimated Total Potential Stormwater Storage and Use

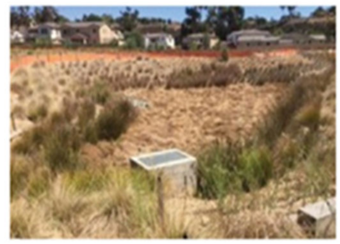
The second step in the model approach is to develop a preliminary conceptual estimate of the potential stormwater storage and use volume for the public parcels identified in Step 1. This step was completed as part of the development of the SWRP (ESA 2017a). The SWRP includes a preliminary estimate of potential storage and use at public parcels in the San Diego region of 92,000 ac-ft/yr. This total regional volume was determined by estimating the stormwater use potential of a very limited number of public parcels and then applying these estimates to the rest of the parcels identified in Step 1. The area available for storage on selected representative parcels was estimated from GIS data, and the San Diego Hydrology Model (SDHM3.0) was used to analyze the hydrology at the limited selected sites. This process is detailed in Appendix H of the SWRP (ESA 2017a).

This analysis is refined for this SWCFS in Step 6 of the model approach, using the full list of stormwater use alternatives (eight compared to three), example projects to conceptualize project layouts, and significantly increasing the number of sites that undergo modeling to refine site storage and use volumes. Screening criteria are also applied to sites that are identified for the use alternatives that include off-site treatment for recycled and potable water use.

2.3 Step 3. Identification of Stormwater Use Alternatives

As presented in **Figure 7**, eight stormwater use alternatives have been identified for captured stormwater in the San Diego region. These uses have been developed based on the review of existing plans developed in the region and in Southern California. The parcels identified in Step 5 are assigned potential stormwater use alternatives from the list presented in Figure 7. The constraints and opportunities associated with each of these stormwater use alternatives are identified and assessed using the example projects discussed in Step 4. Opportunities and constraints associated with each stormwater use alternatives were also discussed at the TAC #2 meeting and the discussion from that meeting has been incorporated in this report.

	Eight Stormwater Use Alternatives
A	Direct discharge to designated groundwater aquifers to be extracted for potable use
B	Discharge to groundwater to reestablish natural hydrology and, by extension, to restore biological uses
C	Irrigation to be used on-site or at nearby parks, golf courses, or recreational areas on public parcels
D	Small scale on-site use for irrigation and other private use on private parcels
E	Flow-through to sustain vegetation in natural treatment system (wetland treatment) and/or restoration sites
F	Controlled discharge to waste water treatment plants for solids management during low flows
G	Controlled discharge to waste water treatment plants for indirect potable use
H	Controlled discharge to waste water treatment plants for recycled water use



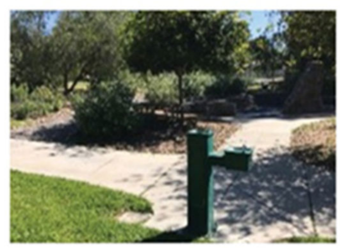


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Figure 7
Stormwater Use Alternatives

The following sections outline the general type of projects that can be considered for each of the eight stormwater use alternatives as listed in Figure 7, and the important elements of quantifying these projects. The example projects that are presented under Step 4 represent each of the general types of stormwater use projects.

2.3.1 Direct Discharge to Designated Groundwater Aquifer and Extraction for Potable Use

Projects that consist of direct discharge to designated groundwater aquifers and extraction for potable use will be developed using example or case study projects that have been implemented, planned, or developed as a concept in San Diego County. Example projects from outside the region may be used, where applicable, to provide additional quantification and cost information for this study due to the more limited opportunities in San Diego County. As shown in Figure 5, the number of designated groundwater basins is limited in the San Diego Region. These unique regional characteristics are important in the assessment of the opportunities and constraints associated with this use category.

Appendix A, Figure A-1 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use consists of directing stormwater (both dry and wet weather flows) to an above ground detention or below ground storage vault/gallery, and then either allowing for direct infiltration, if located above a groundwater basin, or directing stored stormwater at a control rate to an injection well system or recharge area at the designated groundwater basin. Stormwater can also be diverted from MS4 systems and flood channels into storage facilities. Pre-treatment of these flows may be needed to meet groundwater injection/recharge requirements. Stormwater that is infiltrated or injected into the groundwater aquifer can then be withdrawn using extraction wells for further treatment for potable use.

2.3.2 Water Quality Project with Infiltration to groundwater to reestablish natural hydrology and, by extension, to restore biological uses

While direct discharge to a potable groundwater basin is preferable, designated groundwater basins are limited in the San Diego region as shown on Figure 5. Infiltration to subsurface flows outside of these designated groundwater basins still provides a beneficial use toward restoring natural hydrology. The natural hydrology has been altered in urbanized areas through increased runoff and lower seepage volumes, which historically replenished subsurface flows and contribute to base flows in local creeks, rivers, and wetlands. Reducing surface runoff and increasing subsurface flows reduces the impacts of hydromodification in local streams. This restored hydrology, in turn, is expected to improve biological systems that have been disturbed by the altered subsurface flow system.

Appendix A, Figure A-2 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use can be achieved through capturing stormwater or dry weather flows in above ground basins or subsurface vaults/galleries, or in LID best management practices (BMPs), such as green streets. Stormwater and dry weather flows that are captured and stored in these facilities can be infiltrated and filtered through subsurface soils where geotechnical conditions are suitable. San Diego is predominated by low permeability soils with low seepage rates that can limit subsurface seepage rates, so it may be necessary to use stormwater in another way (e.g. biofiltration). It is also possible to divert water from an existing storm sewer system (MS4) if the site is not large enough to capture stormwater or dry-weather flows up to its use capacity. The capture volume will be determined based on site size, and access to existing stormwater will be inferred from distance to an MS4 outfall and the outfall size. The capacity for storage will be estimated from parcel size. The infiltration rates will depend on the subsurface soil conditions.

2.3.3 Irrigation: on-site, at nearby recreational areas, or public parcels

Appendix A, Figure A-3 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use is achieved by capturing stormwater or dry weather flows on-site, or diverting water from an existing storm sewer system (MS4), and then temporarily storing stormwater in an above ground or underground vault system, in order to use it to supplement irrigation and/or grey water needs at an adjacent or on-site park, recreation facility, or golf course. The capture volume will be determined based on-site size and access to existing stormwater. The feasibility of this use will be determined by available stormwater, proximity to irrigation needs, and the estimated required irrigation volumes at those sites. Stored stormwater is then treated to remove trash, sediment, and bacteria by processes meeting Title 22 standards (for above ground use, i.e. spray systems) or applicable codes (for below ground use, i.e. drip systems). Consideration of this use should, therefore, consider space required for treatment systems depending on the type of irrigation and applicable regulatory requirements. The treated water is placed into temporary storage before being distributed for irrigation (above ground spray systems or below ground drip systems) or for toilet flushing at the site.

2.3.4 Small-scale on-site irrigation, and other uses on private parcels

Appendix A, Figure A-4 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. Although at a smaller scale than the previous stormwater uses on public lands, this category includes capture and use for irrigation of landscaped areas or as gray water on smaller private parcels. Although smaller in scale, the opportunities for this use alternative are much larger, as they can be applied to any single- and multi-family residences and commercial parcels. Stormwater from the site is collected and stored in rain barrels or cistern storage systems and released into landscaped areas to supplement irrigation. Runoff from building roofs can also be directly diverted to more pervious areas for irrigation and infiltration into subsurface soils. Stored stormwater could also be used as grey water for toilet flushing. For these smaller systems, treatment is typically not required, however, measures should be taken to address vector issues (i.e. mosquitos) and bacteria growth in the storage systems. The San Diego Best Management Practice (BMP) Design Manual recommends a 72-hour draw down time to avoid vectors.

This stormwater use alternative also includes other uses of collected and stored stormwater and dry weather flows on private parcels. Collecting and using stormwater for industrial uses may also be an opportunity for the region. Although this study focuses on public parcel opportunities, examples and case studies of stormwater uses on private parcels are included in Section 3 along with a discussion of opportunities and constraints associated with these examples.

2.3.5 Flow-through natural treatment system (wetland treatment) and/or restoration sites

Appendix A, Figure A-5 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use alternative is achieved by capturing stormwater or dry weather flows on-site from surface runoff, diverting water from an existing storm sewer system (MS4), or diverting water from a nearby creek, stream, or other channel. Captured stormwater and/or dry weather flows are then temporarily stored and discharged under controlled flows to a natural treatment (wetland) system or restoration site. The capture volume will be determined based on-site size and access to existing stormwater and dry weather flows. Captured or diverted water is generally then detained in a fore bay to remove trash, sediment, and other debris, and then discharged at a controlled rate into a wetland natural treatment system. Sites will be screened to select only those with enough area to detain inflows for controlled release. Water that cannot be discharged through the treatment system (due to the controlled rate) can be infiltrated into the subsurface to restore natural hydrology in the area. Finally, water exiting the treatment system is discharged into a receiving water body. These natural treatment systems can be used to reduce constituents, such as nutrients, to improve water quality in the receiving waters. These captured flows can also be directed through restored wetlands after necessary treatment to provide flows that sustain restored habitats.

2.3.6 Controlled discharge to waste water treatment plants for solids management

Appendix A, Figure A-6 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use alternative includes the diversion of dry weather flows from adjacent MS4 or from storm flow conveyance channels that carry urban runoff to an existing sanitary sewer to improve solids management. The sanitary flows may then be used after advanced treatment for recycled water or indirect potable use (Sections 2.3.7 and 2.3.8). Providing solids management in conveyance systems requires ensuring that a minimum sewer velocity is met. This velocity requirement is based on assumptions on the characteristics of settled solids in sewers. It is also based on sewer line size, geometry, slope, and estimated or measured average flow under low flow conditions. Resuspension of solids in sewer lines may temporarily exacerbate odor issues, but may provide odor control in the long-term.

2.3.7 Controlled discharge to waste water treatment plants for indirect potable use

Appendix A, Figure A-7 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. This use alternative includes the diversion of stormwater and dry weather flows from adjacent MS4 and/or site drainage to be temporarily stored, controlled discharge to a sanitary sewer for conveyance to a waste water treatment facility (WWTP) for advanced treatment and use as recycled (Section 2.3.8) or indirect potable use. A constraint that is highlighted in the example projects is the potential of stormwater incompatibility with an existing treatment process at the WWTP. Projects that divert stormwater to existing or expanded WWTP need to determine the rate at which stormwater can be diverted to the WWTP without impacting the capacity of the existing sewer lines and the treatment facility operations which are under discharge permit conditions.

In developing projects for this use alternative, the capacity of the sewershed needs to be assessed based on sewer line size and flow data. The capacity of a downstream WWTP for controlled discharge also needs to be determined based on the revised influent water quality and the facility treatment systems. Stormwater has low organic matter (low biological oxygen demand or BOD) that can alter the influent characteristics and the established treatment processes requiring a controlled rate of diversion to the WWTP. This will vary between treatment facilities and requires assessment of stormwater quality and facility operations and capacity. This analysis will determine the needed storage and rate in which the stormwater can be discharged. These and other constraints are further discussed in Section 3 for the example projects.

This use alternative may be combined with the above solids management use alternative (Section 2.3.6). The additional pulse solids loads that may be brought into the plant as a result of resuspension in sewers is likely to be negligible compared to baseline influent solids loadings to the plant.

2.3.8 Controlled discharge to waste water treatment plants for recycled water use

Appendix A, Figure A-8 presents the general process diagram for this stormwater use alternative based on the components of the conceptual model. The assessment of this use alternative is similar to that described in Section 2.3.7 for potable water use. A key difference between these two alternatives is the effluent water quality standards for recycled water. The rate that stormwater can be discharge to the WWTP is still based on the capacity of the sewer lines and both the capacity and operational requirements of the treatment processes. These different effluent quality standards are expected to yield different allowable sewer flow and allowable stormwater-wastewater blend values.

2.4 Step 4. Identification, Development, and Quantification of Example Projects

The fourth step includes the identification and quantification of example projects or "case studies." These example projects are listed in Section 3 (project descriptions in Appendix B), and are used to inform the feasibility screening criteria applied to the parcels for specific stormwater use alternatives. The example projects also inform the quantities and costs for the refined regional analysis (Steps 5 and 6). By using example projects to inform the process of feasibility screening the parcels and quantifying the potential stormwater use for the screened public parcels, more refined estimates of potential regional stormwater use have been developed for this study.

Through the TAC and the data collection process (ESA 2017b), example projects have been identified for all the eight stormwater use alternatives. Example projects include implemented projects, project undergoing planning that may include initial design and environmental assessment, and concept projects not fully developed at this time.

The example projects' estimated stormwater capture and use quantities are summarized in Section 3. (Estimated costs for implementation, operations, and management will be provided under the next task of the project.) Opportunities and constraints associated with each example project are identified and presented in the project descriptions (Appendix B) using input from the TAC. The quantities, costs, and opportunities and constraints for these example projects can be used as a planning tool for project sponsors/leads that may be considering or developing similar projects or adding stormwater capture and use elements to their projects.

2.5 Step 5. Public Parcel Screening Criteria and Refinement

The fifth step in the SWCFS is to refine the list of public parcels generated in Step 1 through the application of feasibility screening criteria from the constraints identified by the TAC at the TAC#2 workshop and informed from the project examples developed in Step 4. Screening criteria are applied to the 12,731 public parcels for each of the stormwater use alternatives. The outcome of this step is a refined list of feasible parcels for each stormwater use alternative that can then be used to quantify the regional potential stormwater use for each alternative in Step 6. Parcels may have one or more stormwater use alternatives depending on the outcome of the screening. Feasibility screening criteria are informed by the constraints identified by the TAC in the TAC#2 workshop. **Table 1** provides a summary of the feasibility screening criteria applied to the public parcels for each of the eight stormwater use alternatives.

TABLE 1
PUBLIC PARCEL FEASIBILITY SCREENING CRITERIA

Stormwater Use Alternative	Screening Criteria Applied to the Public Parcels	Basis for Criteria
Applied to all parcels	Greater than 1 acre	Sufficient area for storage
	Portion of the site less than a 15% slope	Maximum slope feasible to create storage without significant and costly site grading
Alternative A (Discharge to Groundwater for Potable Use)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater parcel
	Soil infiltration grade of A, A/D, B, or C	Infiltration rates needs to be sufficient to balance storage
	Within a mile of a groundwater basin that is used for potable water supply.	Needs to be near where use is designated
Alternative B (Discharge to Groundwater for Natural Hydrology)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
Alternative C (Irrigation)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
	Within a quarter mile of a park, golf course, or recreational area	Needs to be near where stormwater can be used to augment irrigation
Alternative E (Restoration and wetland treatment)	Major (36-inch diameter) MS4 outfall located within the parcel	Need for sufficient source of stormwater at parcel
	Within 200 feet of an estuary or waterway OR Within a quarter mile of a park, golf course, or recreational area	Needs to be near where flows from the MS4 can be used for restoration or treatment wetlands

Stormwater Use Alternative	Screening Criteria Applied to the Public Parcels	Basis for Criteria
Alternative F-H (Diversion to WWTP)	Within 200 feet of sewer lines for a feasible WWTP	Proximity to existing sanitary sewer line for diversion to a WWTP that has current or near-term capacity

Using a GIS analysis, these feasibility criteria are used to screen the potential parcels and develop a list of feasible parcels for each of the stormwater use alternatives. The goal of this analysis is to evaluate stormwater capture and use potential at a high-level, region-wide, and that this parcel analysis does not eliminate parcels, but identifies parcels that are most feasible for the alternative uses. Managers will need to evaluate parcels on a project-level to determine whether a parcel should be eliminated or are feasible for a stormwater capture and use project.

Figure 8 presents two hypothetical parcels. When considering the applicability of Stormwater Use Alternative F, Controlled Discharge to Wastewater Treatment for Solids Management during Low Flows, it is important that the parcel be near a sanitary sewer line. The parcel on the left is 120 feet (ft) from the nearest sanitary sewer, while the one on the right is over half a mile from the nearest sanitary sewer line. Using the screening criteria listed in Table 1 for Alternative F, the parcel on the left is retained as a candidate for Alternative F, while the parcel on the right is not used to estimate regional volumes in Step 6.

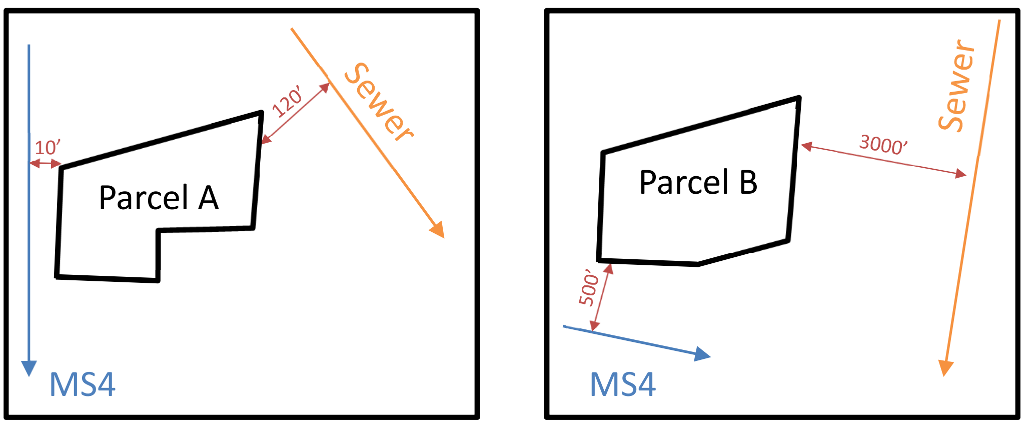

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Figure 8
Conceptual Irrigation Demand and Average Rainfall in Southern California

2.6 Step 6. Parcel List Quantity and Cost Estimate

The sixth step of the SWCFS is to estimate the range of quantities and costs for the applicable parcels screened in Step 5. The result of this analysis is an estimated range in regional volumes and average unit costs for each of the eight stormwater use alternatives. Based on parcel size, catchment potential, and identified potential applicable use, the capture and use quantities and costs for each potential project (a parcel/use combination) will be estimated using hydrologic modeling and assumptions informed by the example projects. The total potential capture and use range of volumes and the range of costs will then be calculated for the entire region. This analysis provides more refined estimate ranges of the potential regional stormwater use compared to the SWRP that can be used to prioritize the alternatives in Step 8.

2.7 Step 7. Develop and Apply Criteria to List of Potential Example Projects and Use Alternatives

The seventh step of the SWCFS is to develop a set of metrics and criteria in order to assess and prioritize the stormwater use alternatives applied to the public parcels. The criteria for the alternatives may include:

- Number and level of identified constraints and opportunities
- Number of benefits achieved
- Total volume annually produced for use
- Cost-volume ratio for use: comparing the cost of implementation, operations, and management to the volume for use

The criteria will be used to inform the prioritization of the different stormwater alternative uses in Step 8.

This assessment of the alternatives for public parcels will provide a basis for regional and jurisdictional planning on the potential application of these alternatives.

2.8 Step 8. Prioritize Stormwater Use Alternatives

The final step in the model approach is to prioritize the use alternatives applicable to the screened public parcels. Prioritization will be based on the metrics and criteria developed in Step 7.

. The prioritization of the stormwater use alternatives applied to the public parcels provides a regional planning tool to identify the alternatives that may be more applicable regionally given the current constraints and opportunities, and which alternatives may be considered feasible in the longer-term. The stormwater use alternatives applied to public parcels will be divided into three categories: short-term, mid-term, and long-term feasibility based on the alternative scoring that reflects the number and level of alternative constraints and opportunities. As an example, the alternative that includes capture and diversion to a wastewater treatment plant for recycled water may have a number of short-term constraints reflected in the scoring that makes this alternative more applicable to mid- and long-term timeline. These constraints include limited existing capacity of existing wastewater treatment plants, restrictions in the diversion rates to WWTP due compatibility of stormwater and wastewater characteristics, and the cost and demand for recycled water. These constraints may change and, for this reason, the planned prioritization represents a planning tool. The objective of this plan is to provide a management tool that can be adaptive as conditions and circumstances of projects and parcels change. Should for example, the capacity of existing WWTP be expanded and demand for recycled water increases to offset greater unit costs, this alternative may be moved to a shorter timeframe.

Managers may use this alternative use prioritization and the constraints and opportunities identified in the example projects as tools to assess and prioritize parcels, projects and programs at a more detailed project-level. For example, managers can use the alternative prioritization process to assess whether their projects are feasible in the short-term based on their identification of fewer constraints that can be more easily overcome and projects that can be readily implemented. Managers may also identify short-term projects based on similar criteria used in the alternative analysis that includes favorable cost-to-volume ratios and multiple benefits such as stormwater and dry weather flow capture using current technologies and existing conveyance and treatment infrastructure. Mid-term-feasible projects may have greater implementation and cost constraints under current conditions, but may become feasible with additional funding, advances in technology or infrastructure expansion that is either planned or under consideration. Long-term projects may be those project which have higher capital costs and require greater public investment, which could be implemented in phases as elements of the larger stormwater capture infrastructure network.

3 Case Studies

Step 4 of the SWCFS process is the identification and quantification of example projects or "case studies". The example projects are used to inform the screening criteria applied to the parcels for specific stormwater use alternatives, and to refine the estimates of potential regional stormwater use. Through the TAC and the data collection process (ESA 2017b), example projects have been identified for all eight stormwater use alternatives. Example projects include already implemented projects, project undergoing planning, and concept projects not fully developed at this time. Concept projects include conceptual evaluations and conceptual pilot scale projects under consideration.

Table 2 provides the list of identified example projects and the use alternatives applicable to the project. The example projects include stormwater use for each of the eight use alternatives. Table 2 also provides the example project's status (conceptual, planning or implemented). Estimated costs for implementation, operations, and management will be provided under the next task of the project. Project descriptions for each of the listed example projects are provided in Appendix B. The example project descriptions provide a project summary, description of the project components, and the quantities estimated for stormwater capture and use.

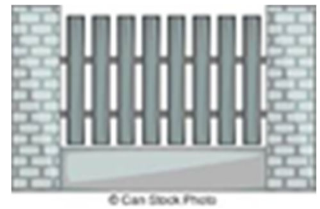
Table 2

Summary of Example Project "Case Studies"

Project Title and Location	Project Type (Status)	Stormwater Use Alternative*							
		A	B	C	D	E	F	G	H
San Diego Zoo Safari Park – Green Parking Lot and Storm Water Capture and Use Project Safari Park, Escondido, CA	Concept	●		●					
Alternative Compliance Retrofit Project at Mountain View Park, Escondido – Biofiltration, Underground Storage and Irrigation Use Alternatives	Concept		●	●					
Diablo Park Alternative Compliance Site – Biofiltration and Underground Storage and Irrigation Alternatives, Escondido	Concept		●	●					
Telegraph Canyon Channel Improvement Project – Expanded Floodway and Bioswales Use for Infiltration	Concept		●						
Lemon Grove Green Street Network – Stormwater Biofiltration and Infiltration	Concept		●						
Woodside Avenue Complete Green Street - Stormwater Biofiltration and Infiltration, Unincorporated Area, San Diego County	Concept		●						
Luiseno Indian Reservation Regional Stormwater Capture Project – Groundwater Recharge, Valley Center	Concept	●	●						
San Marino Drive Green Street and Dry Weather Flow Management -Dry Weather Flow Management and Infiltration, San Diego	Concept		●						
National City "A" Avenue Green Street – Stormwater Biofiltration/Infiltration and Storage for Irrigation for nearby Park, National City	Completed		●	●					
Stone Brewing Company – Stormwater Capture for Small Scale Use for Irrigation and Groundwater Infiltration, Escondido	Completed		●		●				

Project Title and Location	Project Type (Status)	Stormwater Use Alternative*							
		A	B	C	D	E	F	G	H
Dry Weather Flow Diversion at Los Coches Creek Outfall to Wastewater Treatment (Alternative 1), Lakeside	Concept						●		
San Elijo Joint Powers Authority Stormwater Capture and Groundwater Recharge, Extraction, Treatment and Use for Recycled Water, Cardiff by the Sea	Concept	●							●
Franklin D. Roosevelt Park Regional Stormwater Capture and Groundwater Recharge Project, Los Angeles	Completed		●						
Santa Monica Sustainable Water Infrastructure Project, Santa Monica	Planned	●							
Lindbergh Field Terminal 2 Parking Plaza Underground Stormwater Storage, Treatment and Use for Cooling Water	Completed				●				
Mission Valley Stormwater Capture and Groundwater Recharge Project	Concept	●							
Capture, Conveyance and Flow Augmentation to the South Bay Water Reclamation Plant for Recycled Water	Concept								●
Flow Augmentation to the Ray Stoyer Water Reclamation Facility for Non-Potable and Indirect Potable Reuse	Concept							●	●
Olivenhain Municipal Water District 4S Ranch Pilot Stormwater Treatment for Recycled Water	Concept								●

The results of the second TAC meeting included the identification of constraints and opportunities for stormwater capture and use projects that are listed below. Project constraints can be used to assess the potential "gates" through which a project needs to pass to be implemented. Through the identification of these gates, project sponsors can assess the feasibility of the projects and what constraints may be overcome in the future through opportunities or "keys to open gates." Project gates that cannot be "opened" may be identified early in the project planning phase, resulting in an infeasible project. For example, if geotechnical investigation of a proposed groundwater recharge project indicates that underlying soils above the groundwater basin restrict infiltration, then the site characterization gate would be considered closed.



The case studies and identification of constraints (gates) and opportunities (keys) provide a management tool for the assessment of the feasibility of similar stormwater capture and use projects. For each project, the current gates that limit the project are identified and current or future keys, such as future grant funding or interagency agreement to share existing infrastructure and costs, are noted. In some cases, gates may remain closed until the key is developed, such as new technology or a greater demand for recycled water. The listed constraints are used to inform and develop the feasible screening criteria for the public parcels in Step 5. The identification of constraints and opportunities is in the project examples provides a basis for the alternative use prioritization in Step 8, and a tool for managers to assess their projects at a more detailed project-level.

Constraints "Gates"	Opportunities "Keys to Open Gates"
Site Characteristics – Favorable Geology, Complimentary Land Use	*Larger or Multiple Storage Sites* *Complementary land uses*
Match Production with Demand/Need	*Small Scale Implementation* *Multiple Public Parcel Storage Sites* *Market Demand Identified*
Absence of Existing Infrastructure (Storage, Conveyance, Treatment, Distribution)	*Existing Infrastructure (Storage, Conveyance, Treatment Capacity, Distribution)* *Large Scale project – Economies of Scale*
Agency Agreements	*Partnerships*
Water Type Incompatibility Treatment Requirements	*Storage and Controlled Discharge* *Separate or Pre-Treatment*
Regulatory Ambiguity	*Regulator Clarity and Flexibility*
Capital and O&M Costs Funding	*Regulatory Drivers* *Multi-Benefits* *Supportable trade-off between cost and benefit* *Grant Funding*
Public/Agency Support	*Public/Agency Support* *Regulatory Driver* *Public/Private Partnerships*

4 Refined Parcel List and Quantification Results

This section describes the refined parcel (Step 5) and quantification analysis (Step 6) and the resulting preliminary regional estimated ranges in volumes for each use alternative. Once the refined parcel list was developed (Section 4.1), a subset of those parcels was modeled using the SDHM3.1 to determine the volume and timing of stormwater that enters each site over a 40-45-year historic rainfall record (Section 4.2.1). Then, depending on the stormwater use alternative, the volume that could be stored and used over the course of those 40-45 years was determined and an average annual volume was calculated (Section 4.2.2). Lastly, the analysis of the subset of parcels was utilized to extrapolate potential capture volume and use to all of the remaining identified, but unmodeled parcels (Section 4.2.3).

Alternative D, irrigation for private use, was analyzed separately from the parcel assessment as described in Section 4.2.2.4.

4.1 Refined Parcel Analysis (Step 5)

Public parcels were screened using the feasibility screening criteria for each stormwater use alternative presented in Table 1 (Section 2.5). **Table 3** presents the number of parcels initially identified using these feasibility criteria and the selected sub-set of these screened parcels that were modeled in Section 4.2. The scope of this SWCFS limited the number of parcels that could be modeled, so a subset of parcels was identified for modeling based on data availability.

Table 3 also includes the feasibility criteria used to screen the parcels and the number of parcels that were screened out at each step. The lower rows of the table provide the screening criteria used in the SWRP analysis for comparison. For the SWRP, only infiltration to a groundwater basin (Alternative A) and irrigation (Alternative C) were considered for the parcel analysis. The refined analysis shows a very similar number of parcels to the SWRP for irrigation, but shows considerably fewer parcels for infiltration. This is due to the added criteria that a parcel be near an MS4 outlet sized 36 in or greater and that the site soils must be hydrologic soil type A, B, or C (not D).

TABLE 3
REFINED PARCEL ANALYSIS RESULTS

		Feasibility Screening Criteria						
Stormwater use alternative	**# of Public Parcels < 1 ac or no area <15 % slope**	**Location**	**Poor Soil Infiltration**	**No MS4 or MS4 <36”**	**No Current Plant Capacity**	**Infeasible Parcel (in a waterway, etc.)**	**Total # of Parcels Analyzed**	**# of Parcels Modeled**
A – Infiltration to Groundwater Basin	2,395	-60[1]	-2,244	-51	n/a	-11	29	17
A – Injection to Groundwater Basin	2,395	-1,645[2]	n/a	-727	n/a	-14	9	9
B – Infiltration for Hydrology	2,395	n/a	n/a	-2,276	n/a	-31	88	66
C – Irrigation	2,395	-1,516[3]	n/a	-786	n/a	-32	61	51
E – Use for Treatment Wetland	2,395	-851[4]	n/a	-1,431	n/a	-13	100	44
F-H – Wastewater Treatment	2,395	-1,207[5]	n/a	n/a	-1,063	-2	123	6 (57)[6]
Total Uses							**410**	**177**
Total Parcels[7]							**211**	**67**

SWRP Analysis	**# of Public Parcels < 1 ac or no area <15 % slope**	**Location**	**Poor Soil Infiltration**	**No MS4 or MS4 <36”**	**No Current Plant Capacity**	**Infeasible Parcel (based on land use)**	**Total # of Parcels Analyzed**	**# of Parcels Modeled**
A – Infiltration to Groundwater Basin	2,395	-601	n/a	n/a	n/a	-1,215	1,120	n/a
C – Irrigation	2,395	-1,516[2]	n/a	-786	n/a	-6	87	n/a
Total Parcels							**1,207**	**5**

1. Sites not within 1 mile of a groundwater basin
2. Sites not directly above a groundwater basin
3. Sites not within ¼ mile of a park, recreation area, or golf course
4. Sites not within 200 ft of a waterway or lagoon OR within ¼ mile of a park, recreation area, or golf course
5. Sites not within 200 ft of a sewer line
6. Six sites of the 123 near plants with sufficient capacity were modeled, but a total of 57 sites throughout the region near other WWTPs were modeled as well, to evaluate potential capture and use pending expanded WWTP capacity.
7. Some parcels have multiple uses available.

4.2 Stormwater Capture and Use Regional Quantification (Step 6)

4.2.1 Hydrologic Modeling

For each parcel in the subset, the potential drainage area was determined based on a GIS analysis using topographic and MS4 data for the site. Additional data for each MS4 outfall drainage area were gathered to determine land use (defining permeability and friction), slope, and soil type. The SDHM3.1 was then used to model runoff volume and timing to each site based on 40 to 45 years of historic rainfall data from the nearest San Diego ALERT station. The model outputs an hourly time series of flow at the parcel over the 40- to 45-year period.

4.2.2 Stormwater Use Alternative Analysis

Using the time series from the hydrologic modeling, the possible volume that could be used at each site was determined. The following sections describe this analysis for each stormwater use alternative.

4.2.2.1 Alternative A, Infiltration to a Groundwater Basin

Two methods to infiltrate stormwater to a groundwater basin were considered in this analysis: infiltration through an above ground basin, and injection through a well.

Infiltration Basin

Infiltration basins were sized for each parcel based on the available land near an MS4 outfall. A basin depth of 3 ft was assumed using best professional judgement. Additionally, each basin was assumed to have a downstream drain that would drain at a rate that would ensure that standing water does not exceed the 72-hour threshold for vector control, based on infiltration rates per soil type (**Table 4**). For example, a 50,000 square foot (sf) basin could store 150,000 cubic feet (cf) of stormwater (assuming a 3-foot depth) at its maximum. Assuming a soil type of A/B with an infiltration rate of 0.30 in/hr, the basin could infiltrate 21.6 in or 90,000 cf of stormwater in 72 hours. The remaining 60,000 cf of water would need to be drained through the outfall over the 72 hours, so it would require a drainage rate of 830 cf per hour.

TABLE 4
INFILTRATION RATES BY SOIL TYPE

Hydrologic Soil Type	Infiltration Rate (in/hr)
A	0.30 – 0.50
B	0.15 – 0.30
C	0.05 – 0.15
D	0 – 0.15

Using the basin designs and infiltration rates, the volume of stormwater runoff in the basin, the volume infiltrated, and the volume drained were determined for each time step. For the same example basin described above, if a storm event creates a constant flow rate of 4 cubic feet per second (cfs), the basin would have 14,400 cf in it after an hour, or a depth of 3.5 in (0.3 ft). In the next hour, another 3.5 in would be added to the basin, but 0.3 in would be infiltrated and 830 cf or 0.2 in would be drained, for a total storage depth of 6.5 in remaining. If the storm ended at this point, the next hourly time steps would infiltrate another 0.3 in and drain 0.2 in until the basin was empty. This example is shown in **Table 5**. The analysis is then repeated for the full 40- to 45-year time series and the infiltrated volume is averaged per year.

TABLE 5
EXAMPLE INFILTRATION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Depth in Basin (in)	Runoff Depth (in)	Infiltrated (in)	Drained (in)
1	4 (storm begins)	0 (basin empty)	+3.5	0	0
2	4	3.5	+3.5	-0.3	-0.2
3	0 (storm ends)	6.5	0	-0.3	-0.2
4	0	6.0	0	-0.3	-0.2
5	0	5.5	0	-0.3	-0.2
6	0	5.0	0	-0.3	-0.2
7	0	4.5	0	-0.3	-0.2
8	0	4.0	0	-0.3	-0.2
9	0	3.5	0	-0.3	-0.2
10	0	3.0	0	-0.3	-0.2
11	0	2.5	0	-0.3	-0.2
12	0	2.0	0	-0.3	-0.2
13	0	1.5	0	-0.3	-0.2
14	0	1.0	0	-0.3	-0.2
15	0	0.5	0	-0.3	-0.2
16	0	0 (basin empty)	0	0	0
	Total Depth			**4.2 in**	**2.8 in**
	Total Volume			**17,500 cf**	**11,700 cf**

The parcel analysis results found that infiltration basins ranged from 0.4 to 58.8 acres (15,700 to 2,560,900 square feet (sf)) with annual average infiltration volumes of 0.03 to 78.5 ac-ft/yr (1,300 to 3,419,500 cf/yr) for each parcel.

Injection Wells

To use injection wells, it was assumed that an underground vault would be required to store stormwater before it is injected. The vaults were sized for each parcel based on the available land (e.g. open space, parking) near an MS4 outfall. A vault depth of 6 ft was assumed based on best professional judgement.

Injection rates vary depending on hydraulic conductivity of an aquifer, aquifer thickness and area, whether the aquifer is confined or unconfined, depth to water table, and density of injection wells. Injection rates were determined for each parcel based on the California Department of Water

Resources Bulletin 118 Groundwater Basins (1975), with the assumption that injection rates per well would be equal to the average withdrawal rate of production wells reported in Bulletin 118 for the basin. Injection rates varied from 250 – 600 gallons per minute or 0.56 – 1.34 cfs per well. It was conservatively assumed that each basin would have one injection well.

Using the vault designs and injection rates, the volume in the vault and the volume injected were determined for each time step. For example, consider a 50,000 sf vault with a storage volume of 300,000 cf. If a storm event creates a constant inflow rate of 5 cfs, the vault would have 18,000 cf in it after an hour. Assuming the injection well turns on after 5% of the volume in the vault is reached, or 18,000 cf, in the next hour, 2,412 cf would be injected (rate of 0.67 cfs) while another 18,000 cf is added to the vault for a total volume of 33,588 cf. If the storm ended at this point, the next time steps would inject another 2,412 cf until the basin is empty. This example is shown in **Table 6**. The analysis is then repeated for the full 40- to 45-year time series and the injected volume is averaged per year.

TABLE 6
EXAMPLE INJECTION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Volume in Basin (cf)	Runoff Volume (cf)	Injected (cf)
1	5 (storm begins)	0 (basin empty)	+18,000	0
2	5	18,000	+18,000	0 (pump turns on)
3	0 (storm ends)	33,588	0	-2,412
4	0	31,176	0	-2,412
5	0	28,764	0	-2,412
6	0	26,352	0	-2,412
7	0	23,940	0	-2,412
8	0	21,528	0	-2,412
9	0	19,116	0	-2,412
10	0	16,704	0	-2,412
11	0	14,292	0	-2,412
12	0	11,880	0	-2,412
13	0	9,468	0	-2,412
14	0	7,056	0	-2,412
15	0	4,644	0	-2,412
16	0	2,232	0	-2,232
17	0	0 (basin empty)	0	0
	Total Volume			**36,000**

The results found that injection wells produced annual average infiltration volumes of 1.4 to 140.4 ac-ft/yr (60,980 to 6,115,810 cf/yr). The average injection well produced just over four times more than the average infiltration basin.

4.2.2.2 Alternative B, Infiltration for Hydrology

Infiltration basins for Alternative B were sized the same as for Alternative A. Similarly, the infiltrated volume was calculated the same as described above. The difference between the two alternatives comes through the parcel analysis where parcels for Alternative A are required to be above a groundwater basin used for potable use, which is not a requirement for Alternative B.

The results found that infiltration basins have annual average infiltration volumes of 0.03 to 78.5 ac-ft/yr (1,300 to 3,419,500 cf/yr).

The analysis was limited to public parcels where above and below ground infiltration basins could be implemented. The analysis for Alternative B did not include the assessment of infiltration from green street projects, which could be retro-fitted along existing streets. The available data on the location and extent of planned green streets is limited and therefore an estimate of the infiltration rate from these type of projects was not possible. The example projects include more than six example green street projects, and, therefore, provide information on the constraints, opportunities, and estimated quantities and costs of these project for Alternative B.

4.2.2.3 Alternative C, Irrigation

Stormwater collection for irrigation was analyzed using underground vaults sized for each parcel based on the available land near an MS4 outfall and with an assumed depth of 6 ft based on best professional judgement.

Average irrigation rates were calculated based on Estimated Total Water Use (ETWU), measured in gallons per year, in different regions of the county (coastal, inland, mountain, and desert). These annual values were divided over the average number of dry days in the San Diego region, yielding estimated daily use on dry days, which was converted to an irrigation rate in cfs. All parcels fell within the coastal and inland regions, which had the same irrigation rate of 0.004 cfs per acre.

Using the vault designs and irrigation rates, the volume in the vault and the volume used for irrigation were determined for each time step. This analysis is identical to the one described for injection wells, except using the calculated irrigation rate rather than the injection rate. Considering the same example as in Section 4.2.2.2 (50,000 sf vault, with a constant storm flow rate of 5 cfs), **Table 7** presents an example of the model calculation assuming an irrigation rate of 0.004 cfs per acre for a 130-acre golf course.

The results found that the identified parcels could produce an annual average irrigation volume of 0.002 to 38.2 ac-ft/yr (90 to 1,663,990 cf/yr). At the low end of the range, irrigation was limited by park size (i.e. irrigation need).

TABLE 7
EXAMPLE IRRIGATION CALCULATION

Time step (hour)	Runoff to Parcel (cfs)	Water Volume in Basin (cf)	Runoff Volume (cf)	Used for irrigation (cf)
1	5 (storm begins)	0 (basin empty)	+18,000	0
2	5	18,000	+18,000	0
3	0 (storm ends)	36,000	0	0
4	0	36,000	0	0
74 (3 days later)	0	36,000	0	-1,872
75	0	34,128	0	-1,872
76	0	32,256	0	-1,872
77	0	30,384	0	-1,872
78	0	28,512	0	-1,872
79	0	26,640	0	-1,872
80	0	24,768	0	-1,872
81	0	22,896	0	-1,872
82	5 (new storm begins)	21,024	+18,000	0
83	0 (storm ends)	39,024	0	0
84	0	39,024	0	0
154 (3 days later)	0	39,024	0	-1,872
155	0	37,152	0	-1,872
174	0	1,584	0	-1,584
175	0	0 (basin empty)	0	0
	Total Volume			**54,000 cf**

4.2.2.4 Alternative D, Irrigation for Private Use

Although there are many opportunities for stormwater capture and use on private properties, quantifying the potential regional stormwater volume that could be used beneficially is difficult given the private ownership of these properties. Larger scale stormwater capture and use projects have applicability to new and re-developed commercial properties and larger residential developments, which also are required to meet stormwater quality and hydromodification requirements. Stormwater capture and use projects at these sites may be sized larger than the design capture volume and provide for alternative compliance credits for other development and re-development projects. Because of this potential opportunity for stormwater capture and use on private property, example projects for this alternative have been included in the example projects (see Section 3 and Appendix B). Due to the difficulty of estimating the potential regional opportunities due to limited data and land ownership/control, this SWCFS focuses on estimated quantities on public lands. Data is available on the capture of stormwater and use for irrigation using rain barrels on residential parcels, and an analysis of these data was conducted for this study.

The volume of stormwater that could potentially be collected and used in a rain barrel annually was roughly calculated. Using an average roof surface area of 2,500 sf and the 40-45-year rain time series from the SDHM3.1, an analysis similar to the one described for irrigation in Section 4.2.2.3 was conducted. It was assumed that each parcel had 1,250 sf of garden or lawn to irrigate and the same irrigation rate of 0.004 cfs per acre was used.

The results found that one rain barrel could produce an annual average irrigation volume of 0.002 ac-ft/yr. The volume is smaller than the other alternatives due to the smaller storage volume.

4.2.2.5 Alternative E, Use for Treatment Wetland

Underground vaults were sized for each parcel based on the available land near an MS4 outfall. A vault depth of 6 ft was assumed based on based on best professional judgement.

Because wetland restorations or treatment wetlands would only need irrigation during the dry season, dry weather flows were estimated for each parcel. Measured dry weather flows in the region showed that roughly a quarter of monitored sites received dry weather runoff (Wood PLC 2017). Assuming that sites with the largest drainage areas would have the most dry weather flow, the 25% of parcels with the largest drainage areas were identified. An average flow rate was determined from the runoff data and applied at each site.

Using the vault designs, dry weather flows, and an assumed wetland irrigation rate of 1 cfs, the volume in the vault and the volume used for irrigation were determined for each time step. This analysis is identical to the one described for irrigation, except using 1 cfs for the irrigation rate and using dry weather flows instead of storm flows. See the example in Section 4.2.2.3.

The results found that the identified parcels could produce an annual average irrigation volume of 27.1 ac-ft/yr.

4.2.2.6 Alternative F-H, Wastewater Treatment

Underground vaults were sized for each parcel based on the available land near an MS4 outfall. A vault depth of 6 ft was assumed based on best professional judgement.

Sewer system capacity for each major sewer segment was determined in the two sewersheds that were evaluated based on available data on treatment plant capacity, for flow augmentation to a downstream WWTP (Padre Dam and South Bay Water Reclamation Plant (SBWRP)). Each sewershed was evaluated separately. The evaluation was performed to determine whether each major sewer segment ("major" being defined as 24-in diameter or greater for the SBWRP sewershed and at least 21-in or greater for the Padre Dam sewershed) has capacity to meet flows from parcel discharge, in addition to its base wastewater flows. Useable storage parcels from the parcel analysis were only assigned once to a given sewer in the system evaluation. Base wastewater flows for a given gravity sewer segment were primarily calculated assuming the pipe flows at 50% full and at 8 feet per second (fps) during low flow conditions, when parcel discharge would be utilized. The estimated discharge flow from each adjacent parcel and from each parcel upstream from a given gravity sewer segment were added. The relative flow depth, or percent full (d/D where d=flow depth and D=pipe diameter) was calculated. For gravity sewers where this value was found to be 75% or less, it was assumed capacity exists to accept parcel discharge. For force main lines, the base wastewater flow was calculated by adding the base wastewater flow from all upstream gravity sewer branches that feed the force main. Flow from all upstream parcels and any parcels adjacent to a given force main were added to this base wastewater flow. Assuming force mains flow at 100% full, the flow velocity was calculated. Force main lines that yielded a flow velocity of 8 fps or under were assumed to have capacity to accept parcel discharge.

Each major sewer segment in each of the two sewersheds was analyzed for capacity following this approach. The evaluation varied the assumed discharge flow per parcel, to determine the maximum discharge flow at which the majority of each sewershed would run at or under capacity. With the exception of a few “bottleneck” locations in each sewershed, where gravity sewer size was seen to decrease substantially, the majority of pipes in both sewersheds were within capacity when parcel discharge flow was maintained at 0.5 cfs.

Next, using the vault designs and maximum discharge rate, the volume in the vault and the volume discharged were determined for each time step. This analysis is identical to the one described for irrigation, except using the discharge rate of 0.5 cfs rather than the irrigation rate. See the example in Section 4.2.2.3.

The results found that the identified parcels could produce an annual average volume of 0.03 to 37.7 ac-ft/yr (1,310 to 1,642,210 cf/yr) to divert to the two evaluated WWTPs for which data on the system capacity was available.

4.2.3 Regional Extrapolation

4.2.3.1 Alternatives A-C and E-H – Parcel Extrapolation

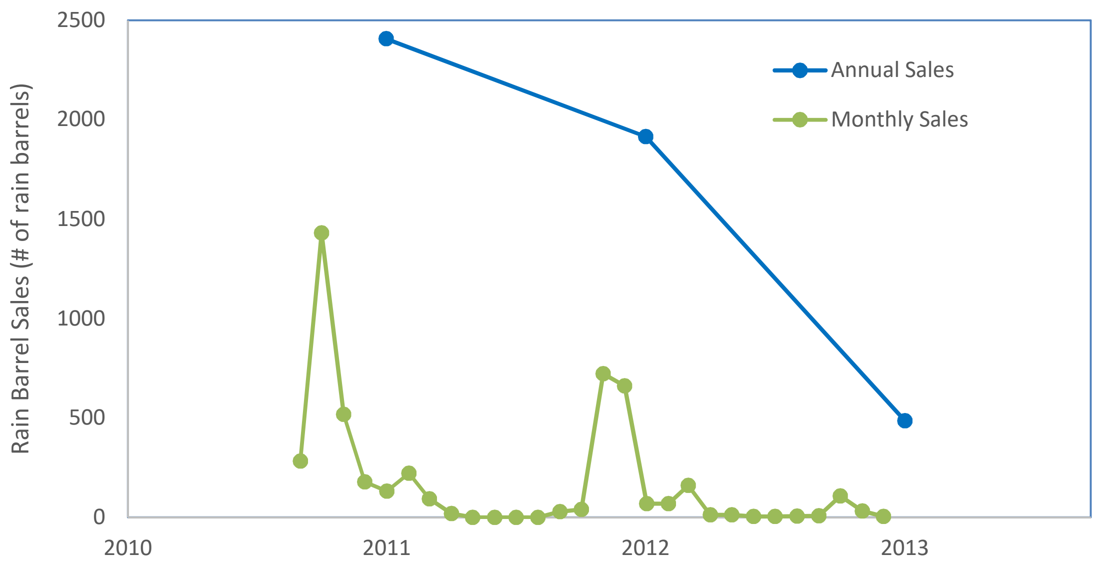
In the results for Alternatives A, B, and C, the MS4 drainage area was found to be the best predictor of annual infiltrated volume for each parcel. An equation was developed to predict infiltration based on drainage area. For parcels where the drainage area was not delineated, an average of 6.3 ac-ft/yr was assumed for Alternatives A and B and 4.4 ac-ft/yr was assumed for Alternative C.

For Alternatives E an average of 27.1 ac-ft/yr was used for all unmodeled parcels. For Alternatives F-H an average of 6.5 ac-ft/yr was used.

4.2.3.2 Alternative D – Rain Barrel Sales Projection

Rain barrel sales data for late 2015 through 2017 were collected from Solana Center for Environmental Innovation (SCEI), which sells rain barrels for the County of San Diego (**Figure 9**). The data show that rain barrel purchases over the last three years have decreased, likely due to a number of conditions: first, decreases in rebates have made rain barrels more expensive to the customer; second, drought conditions increased awareness around conservation, while heavy rains in 2016-2017 may have inspired sales previously. When conditions are right (i.e. cost, promotion, and weather) sales are around 2,500 rain barrels per year. When conditions are not favorable, sales are around 500 rain barrels per year.

The size of rebates from the Metropolitan Water District of Southern California, which have decreased over the last few years, seem to have significant impact on sales. There may also be an opportunity for jurisdictions to improve sales by subsidizing the sales program, or funding advertising, promotion, and other marketing strategies. Assuming a maximum market penetration of 10% of the 1,103,128 households in San Diego (United States Census Bureau 2017), 105,500 barrels could potentially still be sold.



SOURCE: Historic date from SCEI

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Figure 9
Projected Rain Barrel Sales

Using the high and low estimates (i.e. ideal and less favorable conditions) for the next ten years as the minimum and maximum opportunity for rain barrel sales, along with the annual rain barrel capture volume, an estimate of the potential stormwater that can be captured can be calculated. The total additional volume that could be captured ranges from 10 to 50 ac-ft/yr, as shown in **Table 8**.

TABLE 8
TOTAL RAIN BARREL STORMWATER CAPTURE VOLUME

	Number of Rain Barrels Sold	Volume of Stormwater Captured and Used (ac-ft/yr)
Currently in Use	4,808	9.6
Minimum Projection	+5,000 (in next 10 years)	10
Maximum Projection	+25,000 (in next 10 years)	50

4.2.3.3 Sensitivity Analysis

Parcel Analysis

For Alternative A, the soils screening criteria is also very restrictive to the number of parcels considered in the analysis, since a majority of soils in the San Diego region have soil type D with low permeability. However, injection wells would penetrate deep enough to potentially not be subject to soil permeability constraints, making additional parcels feasible. This means injection wells could potentially increase the feasibility of infiltration to groundwater basins by 223 parcels assuming any size MS4 outfall within 250 ft of a parcel, but requiring parcels to be directly above an aquifer (and not just within one quarter mile). However, this is an overestimate, since site feasibility depends on hydraulic conductivity of an aquifer, aquifer thickness and area, whether the aquifer is confined or unconfined, and depth to water table, none of which have been evaluated for these additional parcels. Since only half of the parcels modeled were evaluated as feasible for injection based on-site inspection, 9-108 parcels may actually be available for injection assuming the same feasibility ratio.

As Table 3 shows, the largest sensitivity for the parcel analysis for Alternatives A-E is the assumption that parcels would require an MS4 outfall greater than 36 in at the site to receive sufficient stormwater to be feasible. The modeling results show that parcels with outfalls of that size reach the storage capacity of the infiltration basins and/or storage vaults during most storms. This indicates that the assumption is likely conservative and that the sites are storage-limited, rather than supply-limited. **Table 9** shows the number of parcels that would be available for each alternative with varying MS4 outfall assumptions.

TABLE 9
REFINED PARCEL ANALYSIS WITH VARYING MS4 SCREENING CRITERIA

	# of Parcels assuming MS4 >36" on parcel	# of Parcels assuming MS4 >24" on parcel	# of Parcels assuming MS4 >12" on parcel	# of Parcels assuming any size MS4 within 250 ft of parcel
A – Infiltration to Groundwater Basin	29	31	31	48
A – Injection to Groundwater Basin	9	27	32	108
B – Infiltration for Hydrology	88	189	220	617
C – Irrigation	61	89	107	255
E – Use for Treatment Wetland	100	191	221	532
Total Uses	**287**	**527**	**611**	**1,560**

Because the parcel analysis is sensitive to the MS4 assumption, results are presented in Section 4.2.3.4 for both 36 in MS4 outfalls and any outfall within 250 ft of a parcel.

For Alternatives F-H, the parcel analysis was sensitive to the capacity of the nearest WWTP. If WWTPs are expanded in the future, the additional capacity at other plants could open up more opportunities. If all of the WWTP in the region had additional capacity, an additional 1,017 parcels could be included for consideration. Results based on the potential of an increased in WWTP capacity are presented as the upper range in Section 4.2.3.4.

Stormwater Use Alternative Volume Analysis

Alternatives A and B: Infiltration

For both infiltration analyses, sensitivity was evaluated for infiltration rate within each soil group. As indicated in Table 4 in Section 4.2.2.1, infiltration rates can vary significantly, even if the soil group is known. For this study, the upper limit of each range was used to determine the highest amount of stormwater reasonably infiltrated. The lower limit was used in a second analysis to investigate sensitivity, and this analysis indicated that infiltration volumes could be as much as 55% lower within the infiltration rate ranges for each soil group.

Alternative C: Irrigation

For the irrigation analysis, sensitivity was evaluated for irrigation area and for irrigation practice. An investigation of irrigation area indicated that small irrigation areas emphasize the capacity-limited response of these parcels. With small irrigation areas, stormwater captured and stored at a parcel cannot be used quickly enough to empty the storage vault before the next rainfall event, and the excess must be drained.

Irrigation use is also influenced by irrigation practice decisions. For this analysis, irrigation began after three dry days – days with less than 0.001 cfs of inflow. The number of dry days before irrigation and the threshold for defining a dry day are irrigation practice decisions made by the agency managing the project, and may vary. To test this, a case where irrigation began after seven days with zero inflow (delay of seven days, threshold of zero cfs) was performed and revealed that such a long wait and strict threshold eliminated almost all irrigation use. The other extreme – irrigation at all times – was deemed infeasible and not considered in the sensitivity analysis.

Alternative D: Rain Barrels

For the rain barrel analysis, sensitivity was evaluated for roof size, irrigation area, and regional location (or rain gage). Larger roof sizes did not result in more used volume because the rain barrels are storage-limited. Roofs 600 sf or larger resulted in the same capture and use volume. Similarly, increasing the irrigation area did not impact the results. As long as each rain barrel was used to irrigate at least 150 sf, the use volume remained the same. Lastly, the location of the rain barrel, which determines the amount of rain received, did not impact the results. The model was run for the driest rain gage, in Bonita, and was still found to be storage-limited.

The range in future rain barrel purchases in the region, as discussed in Section 4.2.3.2, shows the most sensitivity for this analysis. The range in number of rain barrels is used as the basis for the range of volumes in Section 4.2.3.4.

Alternative E: Treatment Wetlands

For the wetland analysis, sensitivity was evaluated for different inflow rates and drainage area. Inflow rates at observation stations vary by three orders of magnitude, with a median of 0.025 cfs. To capture the variation, the 25^{th}- and 75^{th}-percentile flows were determined (0.0124 cfs and 0.0625 cfs, respectively) and evaluated. Dry weather observation stations were also compared with the delineated parcel drainage areas in which they lie to look for correlation; however, no significant correlation was identified. This implies that using the high and low flows is appropriate for extrapolation across the San Diego region, rather than a parcel-size- or drainage area-size-based inflow.

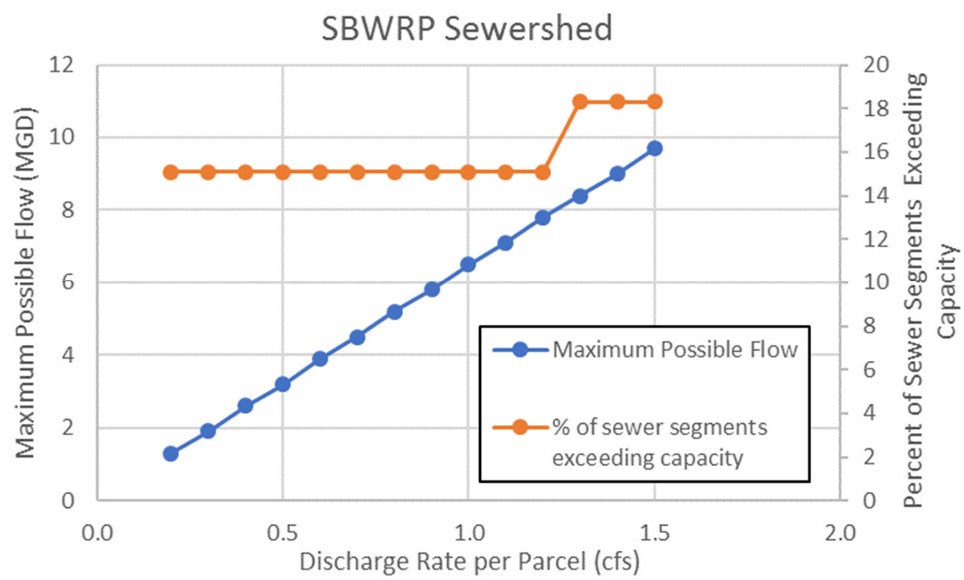
Alternatives F-H: Wastewater Treatment

In the sewer capacity analysis, sensitivity was analyzed with respect to parcel discharge rate (which is connected to parcel storage volume). A discharge rate of 0.5 cfs was assumed to provide adequate stormwater volume in both sewer systems, while not exceeding sewer capacity over the majority of each sewer system. However, parcel discharge rates ranging from 0.1 to 1.5 cfs were evaluated to determine impacts on the maximum possible stormwater flow that could be captured, and on the capacity impacts on the sewer system.

The sensitivity analysis conducted on discharge rate determined, as expected, that the maximum possible flow to the plant available from parcel discharge increases linearly with increase in parcel discharge rate. This is a direct result of the number of parcels contributing to flow with each incremental discharge rate (the number of available parcels changes with each discharge rate, as explained in the next section). On average, when the discharge flow from all parcels increases by 0.1 cfs, this results in an increase in total flow going to the downstream WWTP by about 0.6 million gallons per day in the SBWRP sewer system, (**Figure 10**) and by about 1.1 million gallons per day in the Padre Dam sewer system (**Figure 11**).

The resulting capacity of the sewer system was evaluated in terms of the percentage of the total number of sewer pipe segments in the evaluation that were deemed to exceed capacity in a given system, with an increase in parcel discharge rate. In general, the SBWRP sewer system was found to have about 15 percent of sewer segments exceeding capacity at discharge flows at or under 1.2 cfs. This value jumps to about 18 percent of all pipes when discharge rates exceed 1.2 cfs (Figure 10). The fact that even a low discharge rate results in about 15 percent of sewer segments exceeding capacity is a result of the conservative assumptions applied to the base wastewater flow. These out-of-capacity pipes at a discharge rate of 0.5 cfs or less are concentrated in regions where a major reduction in pipe size occurs, causing a bottleneck for the upstream base wastewater flow. This is explained in more detail in Appendix C.

In the Padre Dam sewer system, under 8 percent of sewer segments were found to exhibit capacity issues at parcel discharge flows 0.3 cfs or less (Figure 11). This percentage rises to about 10 percent and further at discharge flows of 0.4 cfs, to about 17 percent at 0.5 cfs, and to about a third of the system at 1.0 cfs. This is primarily due to several consecutive sewer segments upstream of the influent pump station reaching capacity with parcel flows exceeding 0.5 cfs from upstream parcels are added. In this case, additional parcel flow is likely to affect sewer capacity in the event that parcel discharges from all considered parcels reach this segment of pipe at the same time. A discharge rate of 0.5 cfs is conservatively recommended from parcels, to minimize major capacity issues in the sewer system.



SOURCE: Brown and Caldwell 2018

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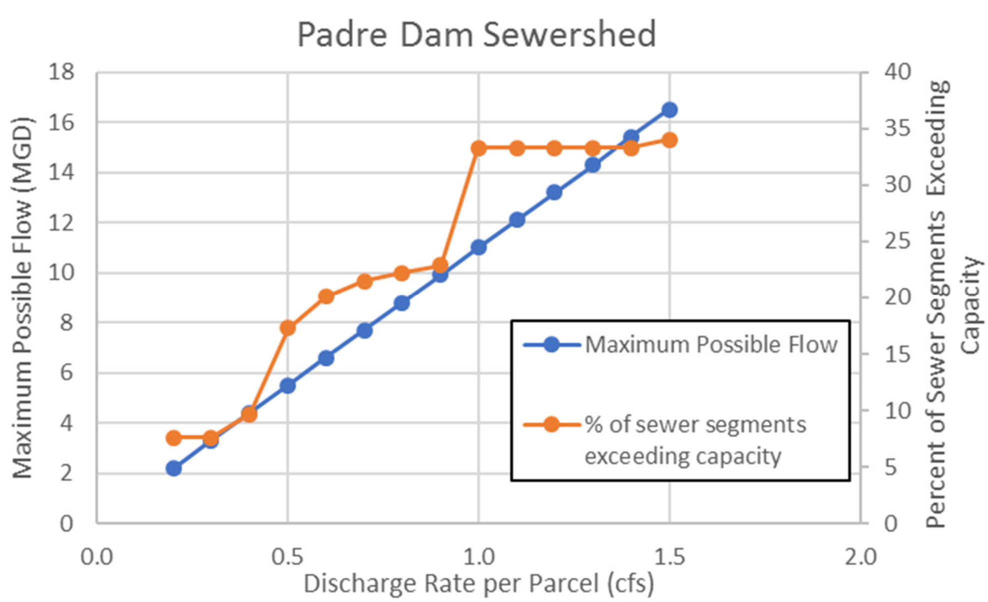
Figure 10
Sensitivity of SBWRP Sewershed Model to Changes in Parcel Discharge Rate



SOURCE: Brown and Caldwell 2018

SWCFS / D140075.20

Figure 11
Sensitivity of Padre Dam Sewershed Model to Changes in Parcel Discharge Rate

4.2.3.4 Potential Regional Stormwater Capture and Stormwater Use Alternative Estimate

Table 10 tabulates the results for each of the alternatives and presents a total regional estimate. Since many parcels could be used for multiple alternatives, the stormwater use alternative that resulted in the highest volume was chosen for the total volume calculation in the last row. The row above this shows the total if multiple uses occurred on the parcels, although the feasibility of this has not been evaluated. For example, if a parcel was identified as feasible for Alternative A and Alternative C, and the quantification resulted in 5 ac-ft/yr for Alternative A and 1.3 ac-ft/yr for Alternative C, this parcel would count toward 5 ac-ft/yr for the total (applying a single max alternative) and 6.3 ac-ft/yr for the total (applying multiples alternatives). However, the total with multiple alternatives may be overestimated since applying both alternatives to a parcel was not evaluated.

TABLE 10
TOTAL POTENTIAL REGIONAL STORMWATER CAPTURE AND USE

	# of Parcels	Total Volume (ac-ft/yr)
Alternative A – infiltration to a groundwater basin		
Infiltration basins	29 – 48	330 – 440[3]
Injection wells	9 – 108	480 – 5,700[4]
Alternative B – infiltration for hydrology	88 – 617	530 – 3,700[3]
Alternative C – irrigation	61 – 255	260 – 1,100[3]
Alternative D – irrigation for private use (rain barrels)	n/a	10 – 50
Alternative E – use for treatment wetlands	100 – 532	680 – 3,600[3]
Alternative F-H – wastewater treatment	123 – 1,140	810 – 7,400[5]
Total (Applying multiple alternatives per parcel):	**410 – 2,700**	**3,100 – 22,000[1]**
Total (Applying single max alternative per parcel):	**211 – 977**	**2,200 – 9,400[2]**

1. Assumes basins with multiple alternatives can utilize all alternatives.
2. Assumes basins with multiple alternatives only use the highest volume alternative.
3. Assumes no MS4 requirement.
4. Assumes no MS4 requirement or soil hydrology requirement, but above a groundwater basin.
5. Assumes no capacity limit for any WWTP.

The total potential range of the stormwater volume that could be captured and used in the San Diego region varies greatly depending on the feasibility screening criteria applied that represents the constraints and opportunities for this region. The lower end of the range is based on the screening criteria applied to the public parcels as presented in Table 3. The upper end of the range represents the results of the sensitivity analysis, and modifications to these screening criteria. These results reflect the high variability associated with this feasibility-level analysis and the data set that is available for this study. Project-specific data can yield less variability. This analysis is supplemented with the quantities and costs analysis at the project-level provided in the example projects (see Section 3 and Appendix B).

The results of this refined parcel analysis are expectedly lower than the original estimates in the SWRP. This refined analysis applies more feasibility screening criteria to the public parcels informed by the example projects and constraints identified during the TAC#2 workshop, compared to the preliminary estimated presented in the SWRP. The refined screening criteria result in a much lower parcel estimate (211) compared to the SWRP (1,207), which is one reason the resulting volumes are much lower. Additionally, the further refinement of the wastewater treatment alternative in discussions with facility operators resulted in a lower discharge rate by an order of magnitude compared to what was used in the SWRP. This reduced the volume by over 60,000 ac-ft/yr.

Although there is high variability in the estimated regional volumes, these results provide a basis to assess each of the stormwater use alternatives for regional and jurisdictional planning as both ends of the range can inform the analysis. The results also indicate that unlike other regions, San Diego has a greater number of constraints (e.g. lower permeability soils, limited groundwater basins, and limited capacity of existing WWTP) that result in a greater sensitivity to the screening criteria applied to the parcels. These planning level estimates, along with costs to be developed in the next phase of the study, will be used as part of the prioritization process to identify the alternatives and project types that provide the best opportunities for stormwater capture and use in the San Diego Region. In addition, the prioritization of alternative uses will identify the "gates" that alternatives need to overcome and the potential "keys" that may open these gates and lead to more opportunities for stormwater capture and use in the region.

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