GROUNDWATER RECHARGE AREAS: IDENTIFICATION AND PROTECTION
WITHIN THE CENTRAL COAST REGIONAL WATER QUALITY
CONTROL BOARD JURISDICTION

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ABSTRACT

Groundwater Recharge Areas: Identification and Protection within the Central Coast Regional Water Quality Control Board Jurisdiction

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This master's project was conducted under the direction of the Central Coast Regional Water Quality Control Board (Water Board) to assist with augmenting their Basin Plan. An investigation of the current practices for identifying and managing groundwater recharge areas was conducted, and strategies for protecting water quality by managing land uses in groundwater recharge areas were developed. Data sources included a review of agency documents, websites, and maps; interviews with stakeholders, and literature research. Data from these sources provided the foundation on which to base strategies for maintaining and improving groundwater quality in the Central Coast Hydrologic Region. This project recommends standard language for groundwater recharge areas, minimum criteria for identifying and mapping these areas, and protection strategies. The Water Board must establish minimum standards to protect groundwater recharge areas, and collaborate with local agencies to protect the quality of groundwater throughout their jurisdiction.

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Introduction

This master's project was completed as partial fulfillment of the requirements of a Master of City and Regional planning from California Polytechnic State University, San Luis Obispo, California. Work was conducted in coordination with, and under the direction of the Central Coast Regional Water Quality Control Board (RWQCB or Water Board).

The Water Board is tasked with protecting and maintaining the beneficial use of waters of the state¹. The overarching document which guides water quality regulation in their jurisdiction is the Basin Plan. The Water Board has determined that the Basin Plan's current groundwater quality regulations and protection strategies need to be strengthened by focusing on existing and potential land use activities in groundwater recharge areas. By investigating current practices for identifying and managing groundwater recharge areas, this master's project intends to assist the Water Board in their effort to augment the Basin Plan and develop implementation strategies to protect these areas.

Objective

The Water Board's Basin Plan establishes the framework for how the quality of the surface and ground waters in the Central Coast Hydrologic Region will be managed to provide the highest water quality reasonably possible (Central Coast RWQCB, 1994).

The Basin Plan provides the regulatory foundation for the Water Board operations; and it is a flexible tool that is revised on a triennial basis to adapt to changing conditions in the region. Although the current Basin Plan has been successful at protecting the quality of

¹ According to Section 13050 of the California Water Code, a water of the state means any surface water or groundwater, including saline waters within the boundaries of the state.

surface water and groundwater on a site by site basis, existing policies need to be strengthened or new policies implemented to address groundwater quality concerns that arise from nonpoint sources and land use related impacts. Nonpoint source (NPS) pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. As runoff moves over and through the ground, it picks up and carries away natural and human-made pollutants (U.S. EPA, 2011). The diffuse nature of NPS pollutants makes regulating these sources more difficult than point sources.

Addressing water quality issues associated with groundwater recharge areas requires the management of land use. Because the Water Board does not have direct authority to regulate land use decisions, it must collaborate and work with local planning agencies within its boundary. This project aims to identify the current state of practice for managing groundwater recharge areas. Furthermore, it intends to develop standard language defining groundwater recharge areas, establish minimum criteria for groundwater recharge area identification and mapping, provide planning strategies to protect these locations, and identify stakeholders to provide feedback and assist with implementing groundwater recharge area protection strategies. The project will provide guidelines that the Water Board can utilize to encourage local planning agencies to follow, to establish a minimum level of protection and continuity throughout the Water Board's jurisdiction. The target audience for these guidelines includes city and county planning departments as well as water resource agencies located in the Central Coast Hydrologic Region.

Background

Almost 75 percent of the world's fresh water is stored in polar ice caps and glaciers, leaving a relatively small amount readily available for use. Groundwater accounts for nearly all of the remaining fresh water on earth with rivers and lakes storing less than one percent of the world's fresh water (Department of Water Resources, 2003). Groundwater is an extremely important source of fresh water in California, accounting for approximately 30 to 40 percent of urban and agricultural demand. Individual communities rely on groundwater to varying degrees based on size and predominant land use. In the Central Coast Hydrologic Region, groundwater accounts for approximately 83 percent of the annual supply used for agricultural and urban needs. This dependence on the resource within the region makes its protection from contamination and degradation imperative.

The agency that is responsible for protecting and maintaining the beneficial use of waters of the state, which include both surface water and groundwater in California, is the State Water Resources Control Board (SWRCB). The SWRCB's effectiveness at addressing water quality issues on a local level is bolstered by the existence of nine RWQCB's that operate under the SWRCB. Each RWQCB is responsible for establishing a Water Quality Control Plan (Basin Plan) to guide regulation within their individual regions. The Basin Plan designates beneficial uses for specific surface water bodies and groundwater basins to be protected, defines water quality objectives which protect those uses, and establishes an implementation plan which accomplishes those objectives.

The Water Board is responsible for protecting waters of the state within the Central Coast Hydrologic Region. This region covers approximately 7.22 million acres (11,300 square miles), and includes Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara Counties and portions of San Benito, San Mateo, Santa Clara, and Ventura Counties (Fig. 1).

There are 50 delineated groundwater basins and 12 subbasins which underlie about one third of the region (Department of Water Resources, 2003). Despite the importance of groundwater as a resource, efforts to protect water quality have typically been focused on surface waters. The contamination of groundwater supplies is currently managed on a site by site basis, with limited success on a regional scale with regard to NPS and land use related impacts.

In 2007, the Water Board formed four teams whose purpose is to implement the Water Board's vision for healthy watersheds. They have been identified as the Assessment, Aquatic Habitat, Clean Groundwater, and Land Use teams. The Clean Groundwater Team established the measureable goal stating "By 2025, 80 percent of groundwater will be clean, and the remaining 20 percent will exhibit positive trends in key parameters²." The Clean Groundwater Team has developed an additional work plan that focuses on groundwater recharge area protection policy (GWRAPP). The objective of the GWRAPP work plan is to identify, prioritize, implement, and monitor groundwater

² Clean Groundwater is suitable for all present and future beneficial uses. Whenever the groundwater quality is better than the quality of water suitable for all present and future beneficial uses, the goal will be to maintain such groundwater quality.

Central Coast Regional Water Quality Control Board Jurisdiction

Source: <http://lib.calpoly.edu/gis/browse.jsp> (Created by Author, 2011)

Figure 1: Central Coast Hydrologic Region

recharge areas within the central coast region. In order to meet the established goals for clean groundwater, the Clean Groundwater Team is working to amend the current Basin Plan. The Basin Plan amendment aims to augment the protection of groundwater by further clarifying the definition of groundwater recharge area, developing a regional groundwater recharge area protection policy, and developing associated groundwater implementation strategies addressing potential land use threats in groundwater recharge areas.

The existing Basin Plan, Porter-Cologne Water Quality Control Act (California Water Code), and SWRCB Resolution No. 68-16 (Statement of Policy with Respect to Maintaining High Quality of Waters in California) and 88-63 (Sources of Drinking Water) provide the Water Board with the authority to initiate regional coordinated efforts with local agencies to protect groundwater recharge areas. “State policy for water quality control in California is directed toward achieving the highest water quality consistent with maximum benefit to the people of the State. Therefore, all water resources must be protected from pollution and nuisance that may occur as a result of waste discharges” (State Water Resources Control Board, 1994, p II-1). Groundwater sources must be protected from pollutants that originate from both point and nonpoint sources of pollution. In addition, groundwater recharge has been identified as a beneficial use in the existing Basin Plan that must be protected. It is defined as follows: “uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers. Ground water recharge includes recharge of surface water underflow” (State Water

Resources Control Board, 1994, p II-24). In order to protect the quality of waters that are recharging groundwater supplies, the land use and surface water interaction must be managed.

The challenge of protecting groundwater from contamination can best be understood through a few basic groundwater concepts. Groundwater can be found in almost any underlying location and it is defined as water located beneath the ground surface in soil pore spaces and in the fractures of rock formations. Key soil properties such as porosity, permeability, and transmissivity help to determine whether the subsurface environment will provide a significant, usable groundwater resource. A body of rock or sediment that yields a significant amount of groundwater is called an aquifer, and when an aquifer or series of aquifers have distinctly defined boundaries they make up a groundwater basin (Department of Water Resources, 2003).

Before water becomes groundwater, it must first percolate into the earth's surface. Land areas where surface water infiltrates into the ground and contributes to the groundwater are generally defined as groundwater recharge areas. The natural characteristics of these locations allow water on the surface to move into the subsurface of the earth and replenish groundwater levels. The same characteristics that make recharge areas effective in replenishing groundwater levels also make these locations more susceptible to degradation because contaminants can easily enter the ground. "As precipitation infiltrates soils and is pulled down by gravitational forces, it dissolves a variety of

materials that it contacts. These materials combine with water to form a leachate³ that transports a variety of inorganic and organic constituents to groundwater aquifers” (Woelkers, et al., 2003, p.2). However, all water entering the earth’s surface is not transporting contaminants. As water enters the earth’s surface a natural filtration system also exists from the soil and vegetation. It is important that surface conditions beneficial to water quality remain in place.

Unlike surface waters, groundwater basins cannot be physically seen and their relatively inaccessible location beneath the earth’s surface makes the protection and monitoring of this resource particularly difficult. Threats to groundwater quality result from land use activities which reduce recharge, and those that introduce pollutants to an area.

Reductions in recharge may lead to overdraft conditions, increased concentration of pollutants, seawater intrusion, and the mineralization of groundwater supplies. The degradation of groundwater quality also occurs due to nutrients and salts loading, the infiltration of polluted runoff, and the introduction of pollutants from urban, agricultural, and industrial activities. Degraded groundwater quality conditions exist in the central coast region and it is anticipated that continued groundwater impacts will occur due to increases in population without the adequate land use management of urban, agricultural and industrial activities on a regional scale. In the central coast region the most frequently encountered water quality problems pertain to excessive salinity or hardness of local ground waters. While these conditions occur naturally in some locations, anthropogenic activities exacerbate the degradation of groundwater quality. A growing

³ Water that carries salts dissolved out of materials through which it has percolated, especially polluted water from a refuse tip.

problem in the region is the increasing nitrate concentrations particularly in the Salinas River Basin, Los Osos Creek Basin, the Santa Maria valley, and near Arroyo Grande (State Water Resources Control Board, 1994) which are the result of human activities, such as agricultural and urban land use activities.

“Groundwater quality and groundwater quantity are interdependent” (Department of Water Resources, 2003, p.3). The interdependent relationship was affirmed by a Supreme Court ruling acknowledging that states have broad authority under the Clean Water Act to protect both the quality and quantity of water. The Clean Water Act does not directly address the question of water quantity but Justice O’Connor stated “any difference between water quality and water quantity was an artificial distinction that had no place in a law intended to give broad protection to the physical and biological integrity of water. In many cases water quantity is clearly related to water quality” (Greenhouse, 1994, p. 1). The interdependent relationship between groundwater quality and quantity often requires the RWQCB to address both factors. Groundwater overdraft exemplifies this inter-reliant relationship. When groundwater is extracted at a greater rate than it is recharged, an overdraft situation occurs. Overdraft is a quantity problem; however, prolonged overdraft may cause water quality degradation due to the concentration of pollutants or the occurrence of seawater intrusion (Peterson, 1991). The negative affects to groundwater sources that overdraft conditions create are a serious concern in the Central Coast Hydrologic Region. The California Water Plan Update, Bulletin 160-98 estimated that most of the overdraft occurring in the state was taking place in three hydrologic regions, one of which is the Central Coast Hydrologic Region. Bulletin 118-

80 identified eleven basins in the state as being in a critical condition of overdraft and two (Pajaro Basin and Cuyama Valley Basin) are located within the Central Coast Hydrologic Region (Department of Water Resources, 2003).

Improving existing groundwater conditions as well as avoiding groundwater degradation is critical because obtaining alternative water supplies or cleaning up contaminated groundwater is expensive and often ineffective (King et al., 1990). Preventative measures such as land use controls are an effective and necessary method of protecting groundwater sources. The serious and often irreversible impacts of groundwater contamination make the planning of land use activities in groundwater recharge areas essential (Yanggen, et al., 1990). This close relationship between land use and groundwater quality requires the coordinated effort between agencies that have the ability to influence land use decisions and those agencies that have the authority to regulate water quality standards to protect the resource.

Groundwater boundaries do not typically align with political boundaries. As a result, successful management requires collaboration on a regional scale. Planning on the local level is where “most land use decisions that have impacts on the quality and quantity of groundwater take place” (King, et al., 1990, p.312). Without coordination between surrounding jurisdictions, groundwater protection efforts may result in limited success for a resource that extends beyond local political boundaries. Currently, a wide range of local and regional efforts are being conducted to address groundwater quality concerns by focusing on groundwater recharge areas within the Central Coast Hydrologic Region.

However, the level of protection and methods in which these efforts are occurring vary widely throughout the region. Geologic and climatic variations in the Central Coast Hydrologic Region account for some of the differences in the efforts being spent to protect groundwater recharge areas. Areas that have highly permeable soils and receive high volumes of precipitation require different land use management strategies than those locations with low permeable soils and low volumes of precipitation to ensure that recharge is occurring with quality water. Despite variations in geographic settings, a minimum level of protection should be established within the eight counties by coordinating efforts between regulators and stakeholders. The Water Board can protect groundwater quality through the management of groundwater recharge areas by improving internal efforts and by developing guidelines that external agencies can adopt.

Methodology

Focusing on land use activities in groundwater recharge areas allows the Water Board to address existing and potential groundwater quality concerns in locations ideal for groundwater recharge and susceptible to contamination. The objective of this project is to assess the current state of practice for identifying and protecting groundwater recharge areas in order to develop regional groundwater recharge areas protection strategies. To meet this objective, specific tasks were identified including: develop standard groundwater recharge area language; establish minimum criteria for identifying and mapping groundwater recharge areas; provide planning strategies to protect these locations; and identify stakeholders to provide feedback and assist with implementing groundwater recharge area protection strategies. Data to support the recommendations and conclusions was acquired from three sources: agency documents, websites, and maps; interviews with stakeholders; and research literature. The three sources allow for the use of triangulation, which confirms the findings of each resource (O’Leary, 2010).

Data Sources

Agency Documents, Websites, and Maps

Existing documents and websites from local agencies within the Central Coast Hydrologic Region, various municipalities statewide, and agencies outside of the state were reviewed for current terminology and best management practices (BMPs). These resources were initially reviewed on a national level to gain an understanding about how groundwater recharge areas and their protection are being addressed from a broad

perspective. However, specific focus was placed on the existing practices within the Central Coast Hydrologic Region. The purpose of reviewing current documents and websites was not only to identify current terminology and existing BMPs, but also to identify gaps in data or insufficient protection efforts. Documents reviewed for each of the eight counties included: General Plans (specifically the Conservation, Open Space, Safety, and Land Use Elements), Integrated Regional Water Management Plans, Stormwater Management Programs, Urban Water Management Plans, Groundwater Management Plans, Master Water Plans, and Hazard Mitigation Plans. State and regional documents included: Department of Water Resources (DWR) Bulletin 118, DWR California Water Plan, DWR Implementing California Flood Legislation into Local Land Use Planning, the California Department of Public Health Services Drinking Water Source Assessment and Protection Program, and the Water Board Basin Plan.

Due to project time constraints and the sheer number of cities that exist in the Central Coast Hydrologic Region it was only feasible to investigate information from the county level. However, focusing on information available through the counties provided an appropriate level of detail for the objective of this project. Counties contain a broad range of land uses which make up both urban and rural landscapes. In addition, county agencies are already conducting regional planning efforts that address land uses and water quality within their jurisdictions.

Groundwater recharge area maps were obtained from county agencies within the Central Coast Hydrologic Region to provide additional information in regard to existing data.

Effective groundwater protection planning requires maps that show where aquifers are the most vulnerable to contamination (Berg, et al., 1999). Groundwater recharge area maps that have already been created help to identify the current level of protection for these specific areas and provide information regarding where the protection of recharge areas needs to be improved. Maps also provide insight as to what criteria has been deemed important by the various agencies that developed the maps for identifying groundwater recharge areas. Groundwater recharge area maps that identify locations susceptible to contamination forms a reasonable basis for regulating land uses (King, et al., 1990; Yanggen, et al., 1990).

Interviews with Stakeholders

Open ended telephone interviews were conducted with individuals who are currently responsible for protecting and managing groundwater recharge areas. Subjects that were interviewed consisted of staff members from public agencies within the eight counties in the Central Coast Hydrologic Region. Survey respondents work in a wide range of disciplines that include: planning, environmental health services, water resources, water quality, Geographic Information System (GIS) services, water engineering, community development, water management, public works, environmental divisions, stormwater management, and water districts. Interviews were also conducted with individuals from state and federal agencies which include: Department of Water Resources, U.S. Bureau of Reclamation, U.S. Geological Survey, U.S. Environmental Protection Agency, California Coastal Commission, Department of Fish and Game, Department of Toxic Substances Control, Department of Pesticide Regulation, Department of Public Health,

National Resources Conservation Services, and the United States Department of Agriculture. Subjects were selected by reviewing existing documents, researching websites, and through recommendations from Cal Poly faculty, staff members at the Water Board, and through the interview process itself. As a result, a stakeholders list was developed and is available in Appendix A of this report.

The following list of eight questions was prepared to help guide the interview process and to ensure that desired information was obtained.

- What term do you use for groundwater recharge areas and how do you define this term?
- What criteria are used to determine recharge area locations?
- How do you prioritize recharge areas?
- Do you currently have documents and policies in place to protect recharge areas and are those documents available to review?
- What problems were present or a concern which led to the creation of groundwater recharge area designations and associated policies?
- Have you mapped recharge areas in your County/Region and are the maps available to review?
- Have programs and policies that have been established been successful?
- What plans does your County/Region have for future groundwater recharge area management?

These questions formed the basis for the interview discussions; however, follow-up questions varied on a case-by-case basis. These additional questions were based on the individual's fields of expertise and the need to obtain specific information that presented itself through the review of existing documents. Unfortunately, not all interviewees were able to address all interview questions, either due to their inability or unwillingness

to answer some of the questions or the lack of knowledge based on the individual's field of expertise. All information incorporated into this project was willingly provided.

Typically, public agencies hire outside consultants to conduct hydrogeologic studies.

The consultants are specialists on the subject and several are currently conducting work in the Central Coast Hydrologic Region. Interviews with these specialists provided an additional perspective for the identification and management of groundwater recharge areas. Four consultants were contacted who conduct groundwater studies in this region. They were identified through local planning agencies, and lists of qualified geologist consultants provided by Santa Clara, San Luis Obispo, and Monterey Counties.

Interviews with consulting scientists were guided by the following questions:

- Do you develop groundwater recharge area maps?
- What criteria are used to determine groundwater recharge areas?
- How do you determine what criteria are used?
- Do you identify critical recharge areas or any type of prioritization?
- What would be the minimum requirements or criteria necessary to develop a groundwater recharge area map?
- What are the costs associated with mapping groundwater recharge areas? What would be the potential cost for a regional groundwater recharge area map that contains the minimum criteria necessary to identify these locations?
- What areas have you mapped? (Are maps typically made for specific basins, regions, or specific locations?) Are these maps available?
- What specific problems or concerns were present which led to the creation of the groundwater recharge area maps?

Research Literature

Additional resources evaluated included: scholarly articles, case studies, books, popular press articles, theses, and dissertations. These sources provided information regarding recent advances in the management of groundwater recharge areas and an analysis of factors affecting groundwater recharge area identification and protection. The literature reviewed was separated into four themes: methods of identifying recharge areas, hydrologic cycle and soil structure, BMPs, and land use planning and management. The literature served to complement the current state of practice assessed through the interview and document review process. It also provided insight for groundwater protection recommendations.

Project Tasks

Standard Language

The first step in developing a groundwater protection strategy is development of standard language. Standard language is important for establishing internal consistency at the Water Board as well as for establishing consistency with agencies throughout the Central Coast Hydrologic Region. Once definitions and terminology for groundwater recharge areas are adopted by the Water Board, local agencies can be encouraged to use the same standard language. Regional coordination and collaboration will be more efficient and effective if agencies are all working with the same basic definitions and terminology.

Identifying and Mapping Groundwater Recharge Areas

Protection of groundwater recharge areas requires that criteria be established to identify these locations. In the most general sense, groundwater recharge occurs in any location where water infiltrates the earth's surface. It is not feasible to regulate all land surfaces where groundwater recharge is occurring; therefore, it is necessary to develop criteria for identifying the most critical recharge areas. These areas are generally defined as locations that provide the primary means of replenishing groundwater supplies that are used for potable water or they recharge aquifers with existing groundwater quality concerns. In addition, areas that are threatened either by existing or planned development should be specifically targeted. Groundwater recharge areas are currently identified based on a wide range of criteria which include, but are not limited to: soil type, geology, land uses, impervious surfaces, impaired aquifers, climate, precipitation, vegetation, and topography. With such a wide range of criteria used to identify groundwater recharge areas, it is essential that minimum or baseline criteria are established. Minimum criteria will establish a consistent approach for protection throughout the Central Coast Hydrologic Region. Agency documents, websites, and maps; interviews with stakeholders; and research literature sources were all investigated to determine what criteria constitutes a minimum standard for identifying groundwater recharge areas.

Develop Planning Strategies

The delineation of critical groundwater recharge areas identifies locations to focus groundwater quality protection efforts. A review of agency documents and websites, academic literature, and interviews with stakeholders was conducted to identify land use

planning strategies which protect groundwater quality. The investigation included land use planning strategies that protect groundwater quality throughout a region as well as those that focus on protecting specific groundwater recharge areas. A review of the documents that house groundwater recharge area protection policies also was conducted. Local agencies have a variety of planning documents that can be developed or augmented to address groundwater quality protection efforts.

Identify Stakeholders

Groundwater management is a complex task that requires the involvement of a wide range of federal, state, and local agencies. Stakeholders were identified by reviewing existing documents, researching websites, and through recommendations from Cal Poly faculty, Water Board staff, and through the interview process. For this project, stakeholders have been defined as federal, state, and county government agencies and staff; and local groundwater experts. These individuals were identified to facilitate the interview process as well as to serve as a reference for the Water Board's subsequent stakeholder collaboration process. Stakeholders may provide important feedback and assistance with implementing groundwater recharge area protection strategies within the Central Coast Hydrologic Region. In order to protect groundwater recharge areas on a regional scale and meet the Water Boards water quality objectives, it is vital that a strong communication system be established between key stakeholders early in the process.

Findings

This section summarizes the information gained through the investigation of current practices identifying and protecting groundwater recharge areas within the Central Coast Hydrologic Region. In addition, it serves as the basis on which implementation strategies were developed. Three types of resources were utilized to investigate the current state of practice: agency documents, websites, and maps; interviews with stakeholders; and additional literature. Information from all three sources was compiled and organized into the following categories: standard groundwater recharge area language; criteria for identifying and mapping groundwater recharge areas; and planning strategies to protect these locations. Information documented in this section intentionally omits the names of the counties being discussed as the purpose of the study is to identify current groundwater protection practices and not to critique.

Standard Groundwater Recharge Area Language

Standard language with specific and well-defined terminology is needed for effective identification and protection of these locations on a regional basis. From the early onset to identify standard language for defining groundwater recharge areas, it was apparent that neither a standard definition nor standard terminology exists. A wide range of terms are used not only to define these locations, but also to simply name them. Some common variations of the term groundwater (or ground water) recharge area which were discovered being used across the nation include: aquifer recharge area, primary recharge area, critical recharge area, recharge area, essential recharge area, sole source aquifer area, sole source recharge area, prime recharge area, important recharge area, significant

groundwater recharge area, sensitive aquifer recharge area, groundwater protection area, recharge zones, zones of contribution, and well head protection area. All of these terms describe locations in which water is infiltrating the earth's surface to recharge groundwater supplies; however, the specific definitions for each of these terms often vary greatly depending on the criteria that the agency utilizing the term has selected. These variations clearly illustrate the need for the Water Board to identify and specifically define standard language which it can implement and encourage local agencies to utilize. Standard language will enhance the capabilities of a regional approach to protect groundwater quality by avoiding potentially significant differences between agencies.

A variety of groundwater recharge area definitions and associated terminology were compiled and are available in Appendix B. Sources for these definitions include: federal agencies, California State agencies, out of state agencies, and local agencies situated in the Central Coast Hydrologic Region. It was found that groundwater recharge areas are defined using different approaches and with drastically different levels of detail. Some agencies define groundwater recharge areas using a tiered approach which introduces terms such as primary or secondary recharge areas. Variations between the definitions often make sense when noting the agency that has defined the term and their specific responsibilities. An example of this is The Department of Public Health which is solely concerned with the quality of drinking water supplies.

A review was conducted to evaluate California State agencies' guidance to local agencies in regard to defining and identifying groundwater recharge areas. Chapter 25 of the

California Water Plan Update 2009 (p. 25-6), developed by the DWR provides some key definitions associated with recharge and also provides a clear definition for a recharge area:

Recharge area - an area where surface water infiltrates into the ground and reaches a saturated zone in either an unconfined aquifer or a confined aquifer. The recharge area for an unconfined aquifer is the ground surface above the aquifer. The recharge area for a confined aquifer is always some distance away from the area where wells have been built that extract groundwater from the aquifer. In at least one case in California a water district overlies a confined aquifer, but the recharge area for the aquifer lies many miles outside the district's boundaries. In other cases recharge of the confined aquifer may occur only where a stream has eroded through the aquitard into the confined aquifer, allowing recharge to occur through the stream bottom, which is below the aquitard.

The definition of recharge area and other key terms included in the DWR report provide potential standard definitions which can be adopted by local agencies. An investigation of documents from the Central Coast Hydrologic Region did not identify any local agencies that acknowledged or referenced this definition or other definitions established by the DWR in their earlier documents.

Of the eight counties which make up the Central Coast Hydrologic Region, only one had clearly defined the term groundwater recharge area. The majority of the counties defined groundwater recharge, and then groundwater recharge areas would be addressed throughout the text in terms of sources for the recharge water and locations where the recharge was either occurring or could potentially occur such as in flood plains or within stream channels. The information provided is important for protecting groundwater quality; however, an easily accessible definition should be supplied. It is evident that

local agencies within the Central Coast Hydrologic Region are not clearly or consistently defining groundwater recharge areas.

The lack of a formal definition for groundwater recharge areas in local planning documents was confirmed through the interview process. Typically when asked how groundwater recharge areas were defined in a particular county, the interviewee would provide a broad definition of the term but did not identify a glossary or document which contained a formal definition. The Water Board has an opportunity to establish standard language and definitions which could be adopted by local agencies within the Central Coast Hydrologic Region. This would initiate the effort to promote regional consistency and enhance regional capabilities for protecting groundwater quality.

Criteria for Identifying and Mapping Groundwater Recharge Areas

Developing minimum criteria for identifying groundwater recharge areas assists with defining the term and narrows down the locations where protection strategies focus.

Criteria used to identify groundwater recharge areas were often included in the definitions. However, groundwater recharge areas were often defined and additional criteria further defining the characteristics of these areas was noted separately.

Regardless of method, documenting the characteristics of a groundwater recharge area requires that criteria are transparent. The criteria provide a basis on which to generate maps that identify the specific location of groundwater recharge areas. These maps are essential for refining and implementing protection strategies in areas susceptible to the degradation of groundwater resources (Harris et al., 1988).

As with establishing a definition for groundwater recharge areas, there are no standard criteria for identifying these locations and no universally applicable method of mapping them. The purpose for identifying groundwater recharge areas as well as the level of detail typically varies significantly from one agency to the next. The review of definitions within the state of California as well as across the nation suggested that potential factors for identifying groundwater recharge areas include: surface and subsurface characteristics (soils, topography, geology, floodplains, direction of groundwater flow, impervious materials, and depth to groundwater); sources of water for infiltration (natural, or artificial); proximity to underlying aquifer; proximity to existing or proposed construction; condition of the receiving aquifer and susceptibility to contamination; the function of the aquifer which is being recharged; and the areas relationship to the hydrologic cycle. A review of additional literature sources supported these factors as potential elements for identifying groundwater recharge areas (de Vries, et al., 2002, Harris, et al., 1988, Lin, et al., 2008, Adams et al., 1992, Brabec, 2009, Barksdale, et al., 1954, Baker, et al., 1990, Berg et al., 1999). They also identified vegetation and climate as two additional elements which have an impact on groundwater recharge areas and may influence the identification of locations to focus protection strategies.

Despite the wide range of potential criteria to consider when identifying groundwater recharge areas, the research provided some insight into a smaller set of essential criteria. Criteria that were consistently noted in the literature for identifying groundwater recharge

areas included: soil permeability and subsurface geology. These two criteria were also repeatedly identified as necessary factors for identifying groundwater recharge areas through the interview process with practicing hydrologists and geologists. For groundwater recharge to occur, it is evident that the soil must be permeable so water can infiltrate the subsurface environment and the underlying geology cannot restrict the downward movement of water and must support the accumulation of retrievable water. The two criteria suggest a minimum standard for identifying groundwater recharge areas for the protection of groundwater quality.

Soil permeability is often used interchangeably with the term hydraulic conductivity and it is a measure of a rock or sediment's ability to transmit water. This ability is affected by the size, shape, and interconnectedness of pore spaces (DWR, 2003). Materials such as sand and gravel have a high permeability and allow water to move into the earth's surface at a much faster rate than materials such as clay or granite, which have low permeability. Due to the typically heterogeneous nature of the subsurface environment, soil permeability is often represented in the field as average values for a large area. Permeability rates lack a formal definition in regard to identifying groundwater recharge areas. There are no standard numbers for defining high, medium, or low infiltration rates. These designations are typically left up to agency discretion and are often expressed as the number of inches per hour water moves through the soil column.

An attempt to identify a standard rate for highly permeable soils characterized in groundwater recharge areas concluded a range from more than 20 in/hr to 0.3 in/hr.

Appendix A of Technical Release 55 from the United States Department of Agriculture identifies hydrologic soil groups which classifies soil types and identifies standard infiltration rates. This document represents a standard soil classification system; however, it may not be solely applicable for identifying groundwater recharge areas. Local agencies need to use discretion to determine what infiltration rates are most appropriate to their jurisdiction. Identifying infiltration rates on a local basis will ensure that institutional knowledge is incorporated and that specific areas in need of protection are identified.

Subsurface geology is the second criterion, which includes a usable aquifer and the hydrologic communication between the surface and the aquifer. As water moves into the earth's surface it is important that it ends up recharging an aquifer, which is a body of rock or sediment that yields a significant amount of groundwater. "Coarse grained sediments such as sands and gravels deposited in alluvial or marine environments tend to function as the primary aquifers in California" (DWR, 2003, p. 85). In addition to the presence of an underlying aquifer additional geological conditions also need to be met. "Fine grained sediments with low hydraulic conductivity, such as clays and silts, often function as aquitards. Aquitards are often referred to as confining layers because they retard the vertical movement of groundwater..." (DWR, 2003, p. 85). An aquitard not only restricts the recharge of groundwater supplies, it also serves as a barrier for contaminants. Aquifers are more likely to become contaminated in areas where aquitards are thin or absent (Berg, et al., 1999). It is important to restrict any pollutants from entering the ground but efforts should be focused in locations where chemicals and

toxins have the potential to ultimately end up degrading existing or potential sources of water for beneficial use.

The two criteria represent locations which recharge the majority of groundwater in the Central Coast Hydrologic Region. However, it is important to recognize that groundwater recharge areas also occur through fractures of bedrock. Although this paper has focused on groundwater recharge areas with permeable soils, it is important that protection strategies be applied to locations where water infiltrates bedrock fractures to recharge groundwater supplies. For the purpose of identifying regional criteria to protect groundwater supplies, these locations have been omitted. If a local agency has knowledge in regard to groundwater recharge areas in bedrock they should include these locations in their protection efforts and in maps which are generated. Small land use changes in groundwater recharge areas with bedrock fractures have the potential to drastically impact and reduce available groundwater supplies. In addition, pollutants which are introduced to these locations have the ability to rapidly move into groundwater supplies.

Another factor important for the process of groundwater recharge is the source of water. This factor was typically noted in the literature and was often expressed by hydrologists and geologists as an additional criterion necessary for identifying groundwater recharge areas. Water that is available for seeping into the earth's surface includes both "natural" recharge and "artificial" recharge. Natural groundwater recharge takes place without the assistance of humans and generally occurs through the beds of rivers and creeks, or the

infiltration of precipitation. Artificial groundwater recharge takes place with the assistance of humans and generally occurs through injection wells, spreading basins, percolation ponds, stormwater retention, irrigation practices, and the managed release of water into stream channels. The distinction between the two sources is important when developing strategies for protecting groundwater quality; however, for identifying groundwater recharge areas all that is needed is that enough high-quality water is available to infiltrate the ground and reach an underlying aquifer.

Both the amount and timing of the water are key sub-factors in determining how much recharge will occur. In regard to precipitation in a semi arid climate like the central coast, “if annual rainfall is distributed relatively uniformly throughout the winter months, little, if any deep percolation will occur because evaporation and plants will consume the water held in the shallow soils before the water holding capacity is exceeded.

Conversely, even in areas with very limited rainfall, if most of the annual rainfall occurs during a couple of the cooler months, deep percolation will occur because the water holding capacity of the soils will be exceeded before the overlying vegetation can consume the stored and accumulating water” (Feeney, 2010, p. 3). The source of water not only has an impact on the process of recharging an aquifer but it is also important in regard to sources of contamination which may degrade groundwater quality.

Anthropogenic activities which introduce pollutants to surface waters in groundwater recharge areas have a much greater threat of accumulating and degrading groundwater supplies.

Locations need to be mapped in order to improve the management of land uses in groundwater recharge areas. “Effective groundwater protection planning requires maps that show where aquifers are the most vulnerable to contamination” (Berg, et al., 1999, p. 321). Obtaining existing maps provides insight into the criteria utilized to identify groundwater recharge areas and also is informative to the level of protection that is occurring in these locations. The advancement of GIS technology has made computer mapping capabilities and the integration of information databases readily available and affordable for local agencies to employ. The programs ability to combine different types of information in a layer format is important for developing groundwater recharge area maps. These maps can be developed using a variety of information that needs to be combined and analyzed. Although some existing maps in the Central Coast Hydrologic Region are only available as paper images, some local agencies have incorporated GIS technology to advance their efforts for identifying and protecting groundwater recharge areas. Having groundwater recharge area information available on a computer database makes the information much more readily available to intra-agency employees as well as outside agencies, thus facilitating better local and regional coordination.

Identifying and Mapping Groundwater Recharge Areas in the Central Coast Hydrologic Region

The identification of two standard criteria (soil permeability and subsurface characteristics) and the importance of mapping groundwater recharge areas provided the basis on which to evaluate the current state of practice in the Central Coast Hydrologic Region. Investigating the current state of practice determined whether or not similar criteria is being utilized and if groundwater recharge areas are being delineated and

protected in practice. Information was obtained through telephone interviews with local agency staff and local hydrologists and geologists. In addition, county planning documents, websites and existing groundwater recharge area maps were reviewed. It is worth noting that detailed information and maps are likely to be available on a project specific basis; however, only countywide maps were researched for the purpose of investigating regional protection efforts.

Results from the investigation concluded that only one of the eight counties in the Central Coast Hydrologic Region had specifically identified soil permeability and subsurface characteristics as criteria for identifying groundwater recharge areas. The county utilized this criteria to identify groundwater recharge areas for the entire region, including both in-stream and off-stream locations. The maps were developed using GIS technology, and the database is readily available from the county planning department website.

Groundwater recharge area identification was based on the two criterions of soil permeability and a geological unit (usable aquifer). Also, only critical groundwater recharge areas were identified, avoiding a tiered approach for identifying and protecting these locations. For this county, soil permeability was the determining factor to identify the locations, and a high permeability rate was selected to be 2 in/hr or greater throughout the entire soil column. However, since the county first began delineating groundwater recharge areas they have discovered that the high soil permeability rate was not protecting all of the necessary aquifers. Soil conditions overlaying some aquifers where the protection of the resource was still necessary did not have infiltration rates that were as high as 2 in/hr. To remedy this situation, the county is now developing a tiered

approach for protecting groundwater recharge areas by identifying secondary groundwater recharge areas with a medium permeability rate of 0.6 in/hr – 2 in/hr for the entire soil column.

Another county has elected to assess groundwater sensitivity throughout the groundwater basin using the EPA's DRASTIC method. DRASTIC stands for depth to water table, net recharge, aquifer media, soil media, topography, impact of the vadose zone, and hydraulic conductivity of the aquifer (United States Environmental Protection Agency, 1987). This method uses criteria established by the EPA for wellhead protection and focuses on identifying areas of the groundwater basin that are particularly vulnerable to contamination. Although this county has identified groundwater sensitivity areas, they are not always effective in protecting groundwater recharge areas for all of the important aquifers especially those that are currently untapped. However, the information obtained from applying the DRASTIC approach has been synthesized and developed into a GIS map that ranks sensitivity levels in six categories ranging from lowest to highest. The map was available in an urban water management plan but GIS data was not available. The information utilized to determine the ranking of locations was not available. In addition to identifying groundwater sensitivity areas, the county also addresses groundwater recharge areas based on the infiltration occurring in streams and in percolation ponds. Maps exist which identify these groundwater recharge areas but they are not readily available to the public.

Five counties in the Central Coast Hydrologic Region identified groundwater recharge areas as either a flood plain or an alluvial streambed. They did not define criteria to delineate groundwater recharge areas on land surfaces away from streams. In-stream soil permeability was often noted as an important criterion for selecting these locations as groundwater recharge areas; however, permeability rates were not identified and additional factors were typically not included. Although soil characteristics in flood plains were noted in one county as a potential location for recharge it also clearly stated that recharge areas have not been identified. Three of the five counties have developed a map delineating the location of groundwater recharge areas. These maps only identify groundwater recharge areas that are in stream, in flood plains, or that are in designated percolation areas. Two of these maps utilized GIS technology; however, the data was not readily available. The other county map is an older black and white image that had text accompanying it to identify groundwater recharge area boundaries.

The remaining county in the Central Coast Hydrologic Region has developed a groundwater recharge map that is only available as a black and white image for a portion of the county. Information could not be found as to the criteria used to develop the map, either in text or through conversations with county staff. Staff members also noted that some of the groundwater recharge areas identified on the older map may actually not be good for recharge and an update of the map is necessary. County documents did note in text that groundwater recharge areas generally occur in locations with highly permeable soils.

From these results it is evident that the majority of counties in the Central Coast Hydrologic Region currently only identify groundwater recharge areas that exist in or along stream channels when developing regional groundwater recharge area maps. Through the interview process it was noted that all eight counties were looking to improve their existing status for identifying and protecting groundwater recharge areas in their jurisdiction. Counties were interested in either developing or improving groundwater recharge area maps and strengthening policies to protect these locations. Some counties had already initiated efforts to improve the identification of groundwater recharge locations as well as strategies to protect groundwater supplies. The focus of these efforts was to develop or amend the following documents: county General Plans, Integrated Regional Water Management (IRWM) plans, Groundwater Management Plans, or Urban Water Management Plans. As local agencies advance their efforts for identifying and protecting groundwater recharge areas, the Water Board has an opportunity to aid in the establishment of regional consistency. Through collaborative efforts, the Water Board can encourage local agencies to utilize minimum criteria for delineating groundwater recharge areas. Key results obtained through the investigation of the current state of practice for identifying and protecting groundwater recharge areas in the Central Coast Hydrologic Region are noted in Table 1.

Table 1: Current State of Practice for Identifying and Mapping Groundwater Recharge Areas in the Central Coast Hydrologic Region

Results	Number of Counties*
Soil permeability and subsurface characteristics were specifically identified as criteria and defined for identifying groundwater recharge areas	1

Results	Number of Counties*
Generally identify groundwater recharge areas and primarily focus on in-stream recharge locations	5
Have developed a regional groundwater recharge area map	6
Utilized GIS technology to develop a groundwater recharge area map	4
Looking to develop or enhance existing groundwater recharge area identification, mapping, and protection strategies	8

Source: Author

* Total of 8 counties make up the Central Coast Hydrologic Region

Through interviews with local hydrologists it became evident that groundwater recharge area mapping typically occurs on a site specific basis opposed to countywide. However, one hydrologist recently conducted mapping on a regional scale for a county in the Central Coast Hydrologic Region. Most hydrologists agreed that developing regional maps can be an effective first level approach to assist with implementing protection strategies; however, due to variations that exist in the field it is important to obtain and incorporate more detailed information moving forward.

A factor which has restricted the development of regional groundwater recharge area maps and poses a barrier for the future is the expense of the task. Hydrologists would not identify expense estimates for developing a countywide groundwater recharge area map. These figures could not be determined due to the site specific nature of the mapping and potential variations in criteria that could be utilized. However, a general consensus noted that a range could exist for the price of mapping. On the low end, a map could be developed for approximately twenty thousand dollars and it could easily reach a couple

hundred thousand dollars on the high end. The range in pricing depends on factors which include but are not limited to the amount of existing information available, data needs, size of the region, and criteria utilized. One hydrologist noted that the mapping could be conducted in phases. Phase one could be conducted simply to establish background information by accessing readily available GIS layers to see what is available for the specific region. This map, along with establishing a GIS database and an accompanying report may cost around twenty thousand dollars. Phase two may include meetings with the planning department to identify specific needs and to develop required criteria. The price of this phase would vary based on the scope of work.

The lack of funding and the limited man hours available for most counties has restricted the impetus for advancing groundwater recharge area delineations throughout the Central Coast Hydrologic Region. However, there was consistency throughout this region as to why the various agencies deemed it important to enhance their abilities to identify groundwater recharge areas. Local agencies stated that the need to accurately identify groundwater recharge areas has arisen due to problems associated with groundwater quality and/or quantity depending on the basin. One county staff member stated that almost every aquifer in their jurisdiction is in overdraft to one extreme or another. Overdraft situations were noted in the majority of the Counties leading to seawater intrusion, groundwater levels dropping, dewatering of wells, and the lowering of stream base flows. In addition, many of the aquifers in the region have water quality concerns due to the introduction of pollutants from land use activities. One county noted that their efforts to identify and protect groundwater recharge areas began as a growth control

measure; however, like the rest of the region the need to address both water quality and quantity concerns led to the recent need for improving efforts to identify and protect groundwater recharge areas. By developing standard language and minimum criteria for identifying and mapping groundwater recharge areas, the Water Board can begin to facilitate protection efforts with local agencies to ensure that the quality and quantity of groundwater supplies is protected or improved.

Planning Strategies to Protect Groundwater Recharge Areas

Defining, identifying, and mapping groundwater recharge areas are important steps toward protecting these locations and groundwater supplies. Maps serve as the basis for policies and implementation strategies to guide land uses that may degrade groundwater quality or development that may interfere with natural recharge processes. There are a variety of methods and actions that protect groundwater recharge areas; however, they are all based on two primary goals. “These goals are (1) ensuring that areas suitable for recharge continue to be capable of adequate recharge rather than covered by urban infrastructure, such as buildings and roads; and, (2) preventing pollutants from entering groundwater to avoid expensive treatment that may be needed prior to potable, agricultural, or industrial beneficial uses” (DWR, 2009, p. 25-5). It is important to achieve these goals for protecting recharge that is either occurring or that will potentially occur through both natural and artificial processes.

Research focuses protection efforts on three distinct types of recharge which include in-stream, off-stream, and injection wells. Water percolating through a streambed

characterizes in-stream recharge, while off-stream recharge occurs in suitable sites outside of the streambed. Injection wells actively pump water into layers of the earth suitable to hold the water. Anthropogenic activities have the potential to negatively influence water quality where each of these three distinct recharge processes occurs. To be most effective in protecting groundwater recharge areas, “protection programs generally should employ a mixture of regulatory and non-regulatory techniques” (Yanggen, et al., 1990, p. 208). Regulatory approaches involve developing legal constraints and guidelines which restrict potentially contaminating activities or land uses. Non-regulatory approaches such as providing public education in regard to best management practices, and land acquisitions or conservation easements on critical groundwater recharge areas have proven to be effective techniques included in a comprehensive system for protecting groundwater recharge areas.

Groundwater recharge area management strategies in California typically focus on land uses, development standards, and the implementation of active groundwater recharge activities. Specific planning documents which house groundwater protection policies include but are not limited to: integrated regional water management (IRWM) plans; groundwater management plans (GWMP), county general plans; zoning ordinances, stormwater management programs (SWMP), urban water plans, and master water plans. Most state guidelines for these documents make little mention of groundwater recharge areas; however, the overall management of water resources often indirectly leads to the management of groundwater recharge areas and their protection. The California legislation has provided groundwater management assistance and guidelines to local

agencies seeking to improve or initiate groundwater protection strategies. The guidelines ensure that specific protection efforts are incorporated into the particular document to be eligible for State funding. State funding and guidelines for the development of water management documents is a major impetus for local agencies to strengthen their protection efforts for the resource. Each document has different requirements and as local communities incorporate some of these plans into their regulatory framework they develop a comprehensive protection strategy.

A review of groundwater management planning strategies and documents was conducted. It was not intended to be comprehensive; rather the goal was to provide a brief overview. Documents specific to the Central Coast Hydrologic Region were also reviewed with the intention to identify where groundwater recharge area protection strategies are located and to identify what types of strategies are being employed. This information informed potential planning strategies that are noted in the recommendation section of this report. A comparison between counties is not necessary due to each county having distinct local characteristics and differing goals for managing future growth and development. The following documents and legislation provide guidance and a framework for local agencies to initiate or further develop efforts to protect groundwater quality.

Integrated Regional Water Management (IRWM) Plan

IRWM is a collaborative effort to manage all aspects of water resources in a region. These plans cross jurisdictional, watershed, and political boundaries and involve multiple stakeholders to address concerns of all entities involved and develop mutually beneficial solutions. In 2002, Senate Bill 1672 created the IRWM Act encouraging local agencies

to work cooperatively to improve water quality, quantity, and reliability. Voters then passed Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act which provides funding for competitive grants for projects consistent with an adopted IRWM Plan. In 2006, Proposition 84, the Safe Drinking Water, Water Quality, and Supply, Flood Control, River and Coastal Protection Bond Act was passed which provides funding for IRWM planning and implementation. Later in 2006, Proposition 1E, the Disaster Preparedness and Flood Prevention Bond Act, which provides funds for IRWM Stormwater Flood Management was passed (DWR, 2011). The guidelines for an IRWM Plan address groundwater recharge as one of the multiple benefits which projects eligible for funding may include; however, the protection of groundwater recharge areas is not a requirement. Local agencies have the option to include groundwater recharge area management into a developed IRWM plan in order to access funding and protect these locations. Table 2 identifies IRWM programs within the central coast funding region and website links to access the plans.

Table 2: IRWM Programs within the Central Coast Funding Region

IRWM Region	Website
Greater Monterey County	http://ccwg.mlml.calstate.edu/irwmp/
Monterey Peninsula, Carmel Bay, South Monterey Bay	http://www.mpwmd.dst.ca.us/Mbay_IRWM/Mbay_IRWM.htm
Pajaro River Watershed	http://www.pvwma.dst.ca.us/project_planning/projects_irwmp.shtml
San Luis Obispo	http://www.slocountywater.org/site/Frequent%20Downloads/Integrated%20Regional%20Water%20Management%20Plan/index.htm
Santa Barbara Countywide	http://www.countyofsb.org/pwd/pwwater.aspx?id=16852&terms=IRWM
Santa Cruz County	http://www.rcdsantacruz.org/pages/resources/integrated-regional-water-management-plan.php
Watersheds Coalition of Ventura County	http://portal.countyofventura.org/portal/page/portal/ceo/divisions/ira/WC/Library/IRWMP_Document

Source: http://www.water.ca.gov/irwm/docs/FundingAreaContacts/SanJoaquinRiver_FA.pdf

A range exists to the extent that groundwater recharge areas are addressed in each local plan within the Central Coast Hydrologic Region. However, common themes for plans addressing groundwater recharge areas include: recharging groundwater with high quality water; integrating recharge with ecosystem benefits; managing drainage; incorporating recharge into development; acquiring key properties for recharge; and establishing policies and ordinances to protect and restore groundwater recharge areas. Although these existing documents begin to address groundwater recharge area protection, there is room for strengthening efforts and increasing the priority of these efforts throughout the region.

Groundwater Management Plan (GWMP)

In 1992, the State Legislature passed AB 3030 (Water Code § 10750 et seq.), the Groundwater Management Act, which provides procedures for a local agency to develop a groundwater management plan. In 2002, SB 1938 was signed into law which requires any public agency seeking State funds through the DWR for the construction of groundwater projects or groundwater quality projects to prepare and implement a GWMP with specific components (DWR, 2011). Although the required components do not address groundwater recharge areas and their protection, suggested data reporting includes component number 11 “Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities,” which provides local agencies the opportunity to include groundwater recharge area protection strategies in this document. “A review of some of the groundwater management plans prepared under AB 3030 reveals that some plans are

simply brief recitations about continuing the agency's existing programs. Not all agencies that enacted groundwater management plans under AB 3030 are actively implementing the plan" (DWR, 2003, p. 44). GWMP's provide local agencies with an opportunity for funding and for establishing policies which will protect groundwater by managing groundwater recharge areas. However, as the DWR's review indicated, it is important that local agencies develop meaningful strategies which will ultimately be implemented. Table 3 provides GWMP information for the counties within the Central Coast Hydrologic Region.

Table 3: Groundwater Management Plans within the Central Coast Hydrologic Region

County	GWMP Title	Basin/Subbasin	Basin/ Subbasin #
Ventura	Santa Rosa Basin GWMP	Arroyo Santa Rosa Valley Basin	4-7
Ventura, Santa Barbara	GWMP	Carpinteria Basin	3-18
Ventura	GWMP for the Fox Canyon Groundwater Management Agency	Oxnard Subbasin Mound Subbasin Fillmore Subbasin Pleasant Valley Basin Arroyo Santa Rosa Valley Basin Las Posas Valley Basin	4-4.02 4-4.03 4-4.05 4-6 4-7 4-8
Ventura	GWMP	Ojai Valley Basin	4-2
San Benito, Monterey, Santa Cruz	Revised Basin Management Plan	Pajaro Valley Basin	3-2
Santa Clara	Santa Clara Valley Water District GWMP	Santa Clara Subbasin Llagas Subbasin Hollister Area Subbasin	2-9.02 3-3.01 3-3.03
Santa Barbara	AB3030 GWMP for the Santa Maria Valley Water Conservation District-Santa Maria Groundwater Basin	Santa Maria Basin	3-12
Santa Cruz	Scotts Valley Water District AB 3030 GWMP: 1999-2300 annual report	Scotts Valley Basin	3-27
Santa Cruz	AB 3030 GWMP Soquel-	Soquel Valley Basin	3-1

County	GWMP Title	Basin/Subbasin	Basin/ Subbasin #
	Aptos Area	Pajaro Valley Basin Santa Cruz Purisma Formation	3-2 3-21

Source: http://www.diablowater.org/links/pdf/CA_Gwmp_List.pdf

General Plan

“Each city and county in California must prepare a comprehensive, long term general plan to guide its future” (Governor’s Office of Planning and Research, 2003, p. 8). This is the overarching document guiding a community’s future development and identifies goals, objectives, policies, and implementation strategies from which all local land use decisions must derive. The general plan has seven required elements and groundwater recharge area protection policies are typically located in the Land Use, Conservation, Open-Space, and/or Safety Elements. Often times a local agency will combine two or more of the required element which is allowable as long as all relevant statutory issues are addressed.

Variations exist as to where groundwater recharge area protection policies are housed within a general plan. Regardless of where the content is located, it is essential that consistency remain throughout the document so that a clear plan for meeting the established goals is present. All eight of the counties in the Central Coast Hydrologic Region identify the importance of protecting groundwater recharge areas, but the methods and level of action to achieve this protection varies greatly. While some counties have developed specific policies focusing on the protection of groundwater recharge areas, others have addressed the protection of these areas as a co-benefit to other planning strategies. The range of established policies topics in the Central Coast

Hydrologic Region include: improving efforts for identifying groundwater recharge areas; improving and expanding groundwater recharge areas designations; land division and density requirements in these locations; prohibiting potential sources of pollution based on land use; stormwater management; and monitoring protection efforts. Table 4 provides the General Plan website for each county in the Central Coast Hydrologic Region as a resource where in-depth information may be obtained for each specific county.

Table 4: Links to General Plans for Counties within the Central Coast Hydrologic Region

County	General Plan
Santa Cruz	http://www.sccoplanning.com/html/policy/general_plan.htm
Monterey	http://www.co.monterey.ca.us/planning/gpu/
San Luis Obispo	http://www.slocounty.ca.gov/planning/General_Plan__Ordinances_and_Elements/Elements.htm
Santa Barbara	http://longrange.sbcountyplanning.org/general_plan.php
San Benito	http://sanbenitogpu.com/docs.html
San Mateo	http://www.sforoundtable.org/P&B/pb_general_plan.html
Santa Clara	http://www.sccplanning.org/portal/site/planning/agencychp?path=%2Fv7%2FPlanning%2C%20Office%20of%20%28DEP%29%2FPlans%20%26%20Programs%2FGeneral%20Plan
Ventura	http://www.ventura.org/rma/planning/general_plan/general_plan.html

Source: Author

Recently, requirements for identifying and mapping locations where floodwaters may accommodate groundwater recharge were established in California State flood legislation. In 2007 several bills were signed by Governor Schwarzenegger which added to and amended state flood and land use management laws. Assembly Bill 162, specifically Government Code Section 65302 requires that cities and counties located in California review the land use, conservation, and safety elements of the general plan for the consideration of flood hazards, flooding, and floodplains to address flood risks (DWR, 2010). Cities and counties “are now required to identify rivers, creeks, streams,

flood corridors, riparian habitat and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management in the conservation element. The intent is to conserve areas used for groundwater recharge and stormwater management and to minimize urban development in these areas” (DWR, 2010, p. 32). In addition, cities and counties should consider “Clearly identifying all areas that may accommodate floodwater for purposes of groundwater recharge and stormwater management on maps or graphics within the conservation element” (DWR, 2010, p. 32). Evidence of the effectiveness of this legislation is already present in the Central Coast Hydrologic Region as some counties have already begun to update their conservation elements to include the requirements. This legislation aligns with protection strategies for groundwater recharge areas; however, they only address groundwater recharge areas associated with floodwaters. The assembly bill is an important step in the direction of identifying and protecting groundwater recharge areas but it does not address the full breadth of the locations that need to be identified and protected.

Zoning Ordinance

Zoning provides one of the primary means of implementing a general plan by classifying the allowable uses of land. A zoning ordinance translates the long-term objectives and policies from a general plan into everyday decisions. Through the use of text and maps, a zoning ordinance describes the distribution and intensity of land uses for residential, commercial, industrial, and open space. Regulations in a zoning ordinance include but are not limited to standards for minimum lot size, building footprints, parking requirements, and other development parameters for each specific land use zone. Each city and county develops its own zoning ordinance to reflect their desires for future

growth, and individual objectives for the physical development within their jurisdiction. Table 5 provides a link to each county zoning ordinance in the Central Coast Hydrologic Region. Although most zoning ordinances in the Central Coast Hydrologic Region do not include specific groundwater recharge area regulations, zoning tools are available to incorporate groundwater recharge area protection into the existing plans. “Overlay zoning is well suited to protect environmentally sensitive areas having a geographic location that does not coincide with the underlying zoning district” (Yanggen, et al., 1990, p. 208).

Table 5: Links to Zoning Ordinances for Counties in the Central Coast Hydrologic Region

County	Zoning Ordinance
Santa Cruz	http://www.codepublishing.com/ca/santacruzcounty/
Monterey	http://www.co.monterey.ca.us/building/docs/ordinances/ordinances.htm
San Luis Obispo	http://www.slocounty.ca.gov/planning/General_Plan__Ordinances_and_Elements.htm
Santa Barbara	http://www.sbcountyplanning.org/permitting/ldpp/auth_reg/ordinances.cfm
San Benito	http://www.amlegal.com/nxt/gateway.dll/California/sanbenitocounty_ca/sanbenitocountycaliforniacodeofordinance?f=templates\$fn=altmain-nf.htm\$3.0&global=hitdoc_g_&hitdoc_g_dt=altmain-nf.htm
San Mateo	http://www.co.sanmateo.ca.us/vgn/images/portal/cit_609/9441580Zregs-wp.pdf
Santa Clara	http://www.sccgov.org/portal/site/planning/agencychp?path=%2Fv7%2FPlanning%2C%20Office%20of%20%28DEP%29%2FPermits%20%26%20Development%2FZoning%20Ordinance
Ventura	http://www.ventura.org/rma/planning/Zoning/ordinances.html

Source: Author

One county in the Central Coast Hydrologic Region has developed an overlay district which limits the minimum lot size for a parcel in a designated groundwater recharge area. In addition, land use activities with the potential for introducing pollutants into the groundwater system are restricted from this overlay district. Specific zoning requirements for groundwater recharge areas does not completely restrict all development

that has a potential to pollute groundwater resources, flexibility for land use activities in the overlay district exists with the option of a conditional use permit. Conditional uses are not allowed as a matter of right due to special problems or hazards that they present. If mitigation measures can be implemented to remove potential threats associated with the land use then it may occur in the specified overlay zoning district after receiving approval from a public hearing.

The majority of the counties in the Central Coast Hydrologic Region currently do not have overlay districts or zoning regulations that specifically target the protection of groundwater recharge areas. Regulations restricting development in a variety of different ways such as restricting new buildings in floodplains, requiring low impact development (LID) strategies, managing drainage, and managing development intensity all indirectly have an impact on the ability of a location to recharge groundwater supplies. While these development strategies are already in place, additional standards should be developed in locations which have the greatest impact for recharging groundwater and locations with the most serious threat to allowing pollutants to infiltrate the surface and degrade aquifers.

It is also important to recognize that developing an overlay zone and making changes to a zoning ordinance is sure to be met with some opposition. “A long tradition of self-reliance and independence has contributed to a reluctant acceptance of measures that might restrict individuals from complete freedom to do with their land as they please” (King, et al., 1990, p. 312). Although overlay zoning can be an effective method to

protect groundwater recharge areas it is important to inform local citizens in regard to the benefits and impacts of such changes. Local agencies should seek community acceptance for the plan prior to moving forward.

Stormwater Management Program (SWMP)

The National Pollutant Discharge Elimination System (NPDES) Stormwater Program regulates stormwater discharges from three potential sources: municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. The permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters such as streams, rivers, lakes, or coastal waters. MS4 operators must obtain a NPDES permit and develop a stormwater management program. Enacted in 1990, Phase I of the program requires medium and large cities or certain counties with populations of 100,000 or more to obtain NPDES permit coverage for their stormwater discharges. In 1999, Phase II was enacted which requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges.

Regulated MS4s are required to implement a SWMP to reduce the contamination of stormwater runoff and prohibit illicit discharges. The USEPA and SWRCB have determined that a SWMP will be considered to reduce pollutants to the maximum extent practical if it fulfills the following minimum control measures: 1) public education and outreach; 2) public participation and involvement; 3) illicit discharge detection and elimination; 4) construction site runoff control; 5) post-construction stormwater

management; and 6) pollution prevention/good housekeeping for municipal operators. This particular document does not specifically address the protection of groundwater recharge areas; however, managing stormwater pollution has an important impact on the quality of water that will be recharging groundwater supplies. “Contaminants or pollutants contained in stormwater include sediments, pathogenic (disease-causing) organisms, heavy metals, volatile and synthetic organic contaminants, chlorides, and nutrients” (Woelkers, et al., 2003, p. 1). Local agencies that are required to develop a SWMP have another opportunity to specifically target the protection of groundwater recharge areas and infiltrating water quality. However, the majority of the counties in the Central Coast Hydrologic Region have not utilized this document to house specific groundwater recharge area protection policies and implementation strategies.

The manner in which stormwater is managed today differs significantly from management strategies in the past. A shift has been made from the old practice of getting stormwater off of a piece of land as quickly as possible and heading toward a storm drain or surface body of water; to realizing the importance of allowing precipitation to infiltrate the earth’s surface. The negative impacts to surface water and the high level of pollutants associated with stormwater runoff has led to the emphasis of reducing the quantity of runoff through a variety of infiltration practices. Recognizing the importance of precipitation infiltration has lead to the desire to reduce the amount of impervious surfaces that result from development and urbanization. Impervious surfaces are incapable of being penetrated and primarily include the development of buildings and infrastructure.

Table 6 provides links to existing stormwater management programs for counties in the Central Coast Hydrologic Region. These programs identify strategies for managing stormwater that directly affects the amount, location, and quality of precipitation that is allowed to infiltrate the earth's surface and become groundwater. Managing the construction and post construction runoff also affects the availability of water for recharge; however, these plans typically do not focus these activities in designated groundwater recharge areas, or in the context of recharging aquifers. Strategies for managing stormwater need to consider if the water originates in a groundwater recharge area so that methods of increasing infiltration and reducing pollutants can be implemented.

Table 6: Links to SWMP's for Counties within the Central Coast Hydrologic Region

County	Stormwater Management Program
Santa Cruz	http://www.dpw.co.santa-cruz.ca.us/SWMP.html
Monterey	http://www.co.monterey.ca.us/msea/Literature/Documents/MRSWMP/MR SWMP%20Revision%201_Jan%2029%202010.pdf
San Luis Obispo	http://www.slocounty.ca.gov/Assets/PW/stormwater/cover.pdf
Santa Barbara	http://www.sbprojectcleanwater.org/swmp.html
San Benito	County stormwater management program was not located
San Mateo	http://www.flowstobay.org/
Santa Clara	http://www.sccgov.org/portal/site/dso/agencyarticle?path=%2Fv7%2FDevelopment%20Services%2C%20Office%20of%20(DIV)%2Fsite_level_content&contentId=d5b6854ad3def110VgnVCM10000048dc4a92_____
Ventura	http://184.73.179.44/vcstormwater.org/

Source: Author

Additional Water Management Plans

There are a host of additional plans that may be developed by a local agency. An urban water management plan (UWMP) is a plan prepared by California's urban water suppliers in order to support their long-term resource planning and ensure adequate water supplies are available to meet existing and future water demands. Every urban water

supplier that either provides over 3,000 acre feet of water annually or serves more than 3,000 or more connections is required to assess the reliability of its water sources for a 20 year planning period to be included in a UWMP. The UWMP is prepared every five years and is submitted to the DWR to ensure that it meets the requirements established in the Urban Water Management Planning Act (Division 6 Part 2.6 of the Water Code §10610-10656). Some counties within the Central Coast Hydrologic Region have developed an UWMP, and discussions related to groundwater recharge typically focus on artificial recharge in both off-stream and in-stream locations. This document provides another opportunity for local agencies to strengthen policies and implementation strategies for protecting groundwater recharge areas.

Local agencies may also opt to develop a master water plan. A master water plan serves to help policy makers, planners, and the public understand the long-range availability of water resources within a particular region. Some counties within the Central Coast Hydrologic Region have developed master water plans, and some discuss the importance of protecting groundwater recharge areas. One plan in particular specifically identifies the location of groundwater recharge areas in text and also ranks them in terms of recharge effectiveness, proximity to areas of need, and availability of recharge water. It is clear that a number of documents are available for local agencies to house policies and implementation strategies for the protection of groundwater recharge areas. A necessary aspect in regard to the various plans is that consistency exists between all of them and that the identified implementation and monitoring strategies are executed.

Attempt by California State Legislation to Enhance Groundwater Recharge Area Protection

In September of 2010, Governor Schwarzenegger vetoed Assembly Bill 2304. This bill would have required a local agency to include a map, or maps, of recharge areas that substantially contribute to the replenishment of the groundwater basin with a description of how those areas substantially contribute in its groundwater management plan for purposes of the state funding requirements. The purpose of the bill was to promote the management and protection of the state's groundwater supplies by requiring groundwater recharge area maps and information to be supplied to local planning agencies (Around the Capitol, n.d.). The bill was vetoed by the Governor and he stated "I am concerned about the impact this bill could have on privately-owned properties, both those currently used as recharge areas and those that might be used in the future. Once mapped and those maps are provided to local governments, the bill intends that these lands will be rezoned to restrict their use to being a groundwater recharge area" (Legislative Counsel State of California, 2011). The bill was vetoed to limit the control of State government on private property and requires local regulatory agencies to establish policies and programs relevant to their specific jurisdictional needs. Local agencies in California have and will continue to identify and map groundwater recharge areas with the intent to protect these locations with the planning tools available to them. The veto of this legislation places the responsibility for managing groundwater recharge areas upon local agencies.

Planning Strategies

A variety of documents are available to local agencies to house policies focusing on the protection of groundwater recharge areas. The strategies that can be employed to achieve

groundwater recharge area protection typically fall within the categories of regulatory/non-regulatory, in-stream/off-stream, and artificial/natural. Across the nation various combinations and levels of strategies that fall into these categories are being implemented to protect the precious resource. The strategies being implemented in each local jurisdiction differ from one to the next because they must reflect the variations in local characteristics and desired goals. The recommendation section of this paper takes a closer look at potential strategies that local agencies can employ to achieve desired outcomes.

Recommendations

The investigation of current practices set the foundation on which to develop strategies for maintaining and improving groundwater quality. The Water Board should first look at actions they can take internally. Then pursue strategies to encourage local agencies to develop individual plans that reflect local characteristics but also compliment regional efforts. The Water Board cannot achieve its stated goal “By 2025, 80 percent of groundwater will be clean, and the remaining 20 percent will exhibit positive trends in key parameters” by working in isolation. Collaborative efforts with local agencies must exist to protect both the quality and quantity of groundwater resources in the Central Coast Hydrologic Region.

The Water Board has the responsibility of maintaining the quality of the waters of the state, but protecting groundwater quality is also important for local agencies to pursue by addressing land use decisions directly impacting local groundwater supplies. All counties in the Central Coast Hydrologic Region have stated their desire to protect and improve water quality by focusing on groundwater recharge areas. The degradation of groundwater supplies can have profound impacts on the economic, social, and safety of a region. This is especially true within the Central Coast Hydrologic Region due to the regions high dependence on groundwater supplies to meet the needs for both urban and agricultural uses. Recommendations and assistance offered by the Water Board should be well received by local agencies as these entities work to protect a valuable resource. Recommendations provided in this section are separated into internal strategies that the Water Board can incorporate into their Basin Plan and operating framework; and external

strategies to encourage local agencies to employ. The Water Board has the responsibility to provide leadership and the impetus for a regional groundwater recharge area protection effort for the Central Coast Hydrologic Region. Both internal and external strategies should address the development of standard language; criteria for identifying and mapping groundwater recharge areas; and the development of protection strategies. Recommendations provided in this master's project are not intended to be prescriptive, rather to provide information that should be considered by both the Water Board and local agencies. As regional protection strategies evolve, it is important to recognize that a one size fits all plan for protecting groundwater recharge areas will not be effective in meeting improved groundwater quality goals. Variations in local characteristics for each jurisdiction must be accounted for.

Internal Approach

Standard Language

The importance of developing standard language for groundwater recharge areas has been well documented, and it is an essential first step for protecting these locations. The existing variations in terminology and definitions for groundwater recharge areas makes it necessary for the Water Board to clearly establish and define the term in its Basin Plan. The definition for groundwater recharge area could be expressed in Chapter 4 (Implementation Plan) of the Basin Plan. The protection of these locations is an implementation strategy for maintaining and improving the quality of groundwater recharge. A definition to consider for inclusion to the Basin Plan considers both the

definition established by the DWR in the California Water Plan Update, 2009 and the definition for groundwater recharge as currently defined by the Water Board.

Groundwater Recharge Areas: Land areas where surface water infiltrates into the ground and contributes to the groundwater stored in an aquifer. Water reaches the saturated zone by way of natural⁴ or artificial⁵ recharge for the purposes of maintaining ecological processes, future extraction, maintenance of water quality, or halting of seawater intrusion into freshwater aquifers. Geological characteristics that make these areas favorable for replenishing groundwater also make them more susceptible to groundwater contamination and reductions in surface water infiltration due to anthropogenic activities.

Providing a clear definition for groundwater recharge areas in the Basin Plan eliminates the potential for confusion when discussions and strategies commence for protecting these locations. The suggested definition is general so as not to exclude potentially significant groundwater recharge areas that may exist in the field. Prior to selecting a definition for inclusion to the Basin Plan, potential definitions should be well vetted by receiving input from stakeholders and community members. Once a general definition has been established then additional criteria can be identified to help further define the term and assist with identifying these locations.

Criteria for Identifying and Mapping Groundwater Recharge Areas

Providing a minimum standard for identifying groundwater recharge areas will allow the Water Board to establish a base level of protection that all local agencies should adhere

⁴ **Natural Recharge:** Groundwater recharge that takes place without the assistance of humans. Recharge may occur naturally through rivers, lakes, wetlands, riparian corridors, stream seepage, precipitation, stream inflow, subsurface inflow from upgradient sources of groundwater, and other water concentrations such as runoff or flooding.

⁵ **Artificial Recharge:** Groundwater recharge that takes place with the assistance of humans. Recharge may occur artificially through injection wells, spreading basins, unlined canals, percolation ponds, management of instream flows, stormwater retention, inefficiencies in water applications, irrigation practices, and the disposal of excess water.

to. Research has indicated that a number of different criteria may be utilized to identify groundwater recharge areas; however, soil permeability and underlying geology are two essential elements that at a minimum should be included in identifying these locations. These criteria should be noted and incorporated into the Basin Plan, providing guidance to local agencies.

The Water Board should identify soil permeability as a required criterion for identifying groundwater recharge areas, and should establish a minimum standard for identifying high permeability. To establish this minimum standard it is crucial that geologist and hydrologist specialists be involved with the determination. Selecting a high permeability rate must be well vetted and have defensible evidence as to why the figure was selected, and how it will protect the quality and quantity of groundwater supplies. Defining this rate will allow the Water Board to ensure that a minimum level of protection is occurring throughout the region. Local agencies have the opportunity to implement high permeability rate standards that are more stringent if they feel it is necessary to achieve their individual goals for protecting the resource. Establishing stricter standards will allow local agencies to consider unique geologic characteristics present in their jurisdiction.

The Water Board should also establish a minimum standard for addressing the second criterion, underlying geology. At a minimum, local agencies should identify and protect aquifers that supply or may potentially supply water for beneficial use. Developing this minimum requirement for considering underlying geology will provide consistency

throughout the Central Cost Hydrologic Region and a base level of protection. With this minimum standard identified, local agencies will again have the opportunity to establish additional factors to consider heightening protection efforts as needed in their jurisdiction. Local knowledge should be considered to define areas that do not restrict the downward movement of water due to the presence of an aquitard. Minimum standards established by the Water Board will allow local agencies to account for unique groundwater recharge areas such as those in the fractures of bedrock as part of their protection effort.

To assist local agencies with the collection of information for identifying groundwater recharge areas, the Water Board should compile a list of available resources that local agencies can access. Providing guidance for acquiring information will help local agencies advance their protection efforts for improving water quality and ensure that reliable resources are being used. The Water Board should also develop a list of qualified geologists and hydrologists that local agencies can contact to facilitate the identification and delineation of groundwater recharge areas.

The Basin Plan should also encourage the use of GIS technology when delineating groundwater recharge areas. This technology is readily available and should be considered the standard for mapping as efforts to protect these locations advance. A GIS database provides decision makers the ability to examine the impacts of selecting different criteria for identifying groundwater recharge areas on land use activities and future water supplies. Local agencies will need to develop their own GIS database but

the Water Board should compile available information and ensure that regional data is available to all interested parties. The database will provide the opportunity for other agencies to easily access the information to begin coordinating protection efforts for the entire Central Coast Hydrologic Region.

Protection Strategies

Prior to encouraging outside agencies to identify and protect groundwater recharge areas, the Water Board must first examine what regulatory mechanisms are currently in place that may already assist with protecting water quality in these locations. This may include an internal review of regulations that address total maximum daily loads (TMDL), point source pollution, nonpoint source pollution (NPS), stormwater, and agricultural runoff. In addition, existing policies that may inhibit efforts to improve groundwater quality by focusing on groundwater recharge areas need to be identified so they can be amended. Thoroughly understanding how existing regulation mechanisms may apply to groundwater recharge area protection will assist the Water Board in augmenting the Basin Plan.

Recommendations in this project only represent one aspect of the requirements for the overall Basin Plan amendment. Appendix C contains a matrix that the Water Board has developed which identifies tasks, subtasks, and deliverables necessary to complete the Basin Plan amendment. The identified tasks include: research and development; staff report; California Environmental Quality Act (CEQA) checklist; draft basin plan amendments; draft resolution; basin plan policy and amendment adoption; and agency alignment/basin plan amendment surveillance. This project has been identified as a

subtask to the draft Resolution. Additional tasks and subtasks in the matrix identify actions that the Water Board needs to conduct to complete the amendment process while adhering to standard amendment procedures.

The incorporation of groundwater recharge area definitions, criteria, and policies to the Basin Plan is an essential step to improve groundwater quality. Once the amendment is completed the Water Board will need to be proactive in ensuring that groundwater recharge area identification and protection efforts are implemented internally as well as throughout their region. Water Board staff will need to be educated in regard to the new policies and the impacts they may have on current and future work. Measures to ensure that Water Board staff is continually updated on new policies should be developed. Intra-office collaboration and networking will be an essential element to assure that such measures are successful.

A clear plan should also be developed to initiate and sustain regular meetings with stakeholders, particularly local planning agencies. Collaboration with local planning agencies is essential for protecting groundwater recharge areas because they possess the authority to regulate land use decisions that have a direct impact on the presence of pollutants and infrastructure that impact groundwater quality. These agencies also have detailed knowledge of their specific regions and can identify the most locally relevant plans and policies for implementation. Appendix A provides a list of potential stakeholders that should be considered for inclusion in the collaboration effort.

The Water Board should develop a memorandum of understanding (MOU) with local agencies. The MOU will describe the agreement established between the Water Board and a local agency, indicating a common line of action and commitment for protecting groundwater recharge by focusing efforts in groundwater recharge areas. Although local agencies will be responsible for actually developing and implementing groundwater recharge area protection policies and strategies, the Water Board can provide information and guidance throughout the process.

One final strategy which must be implemented by the Water Board is a program to monitor the effectiveness of the groundwater recharge area protection efforts. To determine the effectiveness of the GWRAPP program, the Water Board should monitor changes to groundwater quality in the Central Coast Hydrologic Region as well as monitor the progress of planning efforts from local agencies. The ultimate goal of promoting the protection of groundwater recharge areas is to assist with achieving the figures of 80 percent clean groundwater and positive trends in 20 percent of groundwater resources in the Central Coast Hydrologic Region. An existing program that will assist with monitoring groundwater quality trends is the Groundwater Ambient Monitoring and Assessment Program (GAMA). This is California's comprehensive groundwater quality monitoring program that was established by the SWRCB in 2000. The goal of GAMA is to improve statewide groundwater monitoring and increase the availability of groundwater quality information to the public. The availability of this information may assist the Water Board in not only identifying locations where groundwater quality is

maintaining high quality or improving, but it will also be informative to identify where protection efforts need improvement.

An additional program that may assist with monitoring water quality trends is the Central Coast Ambient Monitoring Program (CCAMP). This is the surface water ambient monitoring program for the Central Coast Region that follows a rotational watershed monitoring scheme that assesses each major watershed area once in a five year period. The program also monitors 33 coastal stream confluences monthly for the detection of trends. Monitoring trends in surface water quality will supply important data to the Water Board to see if land use strategies being implemented to reduce pollutants in specific areas are having the desired results. An increase in surface water quality will have a direct impact on the quality of groundwater as this is the primary source of water recharging aquifers.

The Water Board can also monitor the effectiveness of the GWRAPP program by examining the efforts that local agencies are taking to manage land uses in groundwater recharge areas. As MOUs are developed it will be possible to monitor the interest local agencies have in entering such an agreement as well as the level of protection that they are willing to commit to. A review of established MOUs with various agencies will be an efficient method of investigating if the program is being well received in the region. The Water Board should also initiate a regular assessment of local agency documents throughout the Central Coast Hydrologic Region to determine if standard language and groundwater recharge area protection policies are being included. In addition, a review

of implementation strategies is necessary. This will ensure that strategies are not simply being noted as important but that actions are being taken to improve water quality in designated groundwater recharge areas. Obtaining local agency groundwater recharge area maps will assist with efforts for determining if local agency protection efforts are advancing. Without defining and mapping groundwater recharge areas it is not possible to effectively manage land uses in these areas and quality concerns for water recharging aquifers will remain.

External Approach

Standard Language

The definition that the Water Board ultimately decides to include into its Basin Plan should serve as a standard or guideline for local agencies to consider when defining the term within local documents. Consistency in terminology between state and local agencies will improve regional protection efforts. Local agencies should ensure that the selected definition is incorporated into all documents which use the term. The definition can be explained in text or in a glossary as long as readers have a clear understanding of the term when reviewing a document. Ultimately this definition will need to be expanded to contain specific parameter for delineating groundwater recharge areas which will be used to focus land use regulations. Defining criteria for delineating groundwater recharge areas may be included with the general definition or separately as long as the information is available and transparent.

Criteria for Identifying and Mapping Groundwater Recharge Areas

Local agencies must adhere to the minimum criteria requirements that are ultimately included in the Water Board's Basin Plan for identifying and mapping groundwater recharge areas. Local agencies first need to adhere to the permeability rate established by the Water Board. If local agencies feel that the rate identified by the Water Board is not sufficient to protect local resources than a lower permeability rate should be identified as the standard within that region. Research has indicated that the rate of a defined highly permeable soil can vary drastically from one region to another due to variations in geologic characteristics and local designations. The categorization of high permeability is a subjective determination which is ultimately selected in order to protect groundwater resources based on local knowledge and needs. High permeability designations should have a scientifically based rationale, and be determined by a qualified hydrologist or geologist. Utilizing the guidance of experts to identify groundwater recharge areas will ensure that necessary locations are protected and will provide a defensible position if opposition arises as protection strategies are developed.

Information regarding local soil types and permeability rates should first be investigated by reviewing in-house resources. Most local planning departments already contain detailed information and maps that identify soil types throughout their region. If this information is not readily available in-house, then outside sources such as the USGS, U.S. BLM, and the USDA National Resource Conservation Service websites may be useful resources. Once soil maps and information are obtained for a region some

consideration should be given to Appendix A of Technical Release 55 from the United States Department of Agriculture. This resource identifies hydrologic soil groups and classifies soil types with standard infiltration rates. This may provide a good starting point for local agencies to begin identifying locations with high permeability rates; however, it is important to combine this information with data obtained from the field to ensure accuracy.

Local agencies should also adhere to the minimum standards for subsurface geology established by the Water Board. Local agencies should begin their investigation of information in regard to subsurface geologic characteristics in-house. Information regarding groundwater basins and usable aquifers may also be readily available. Outside sources are also available to obtain relevant information which includes the DWR, USGS, and SWRCB websites. Field data should also be incorporated into identifying usable aquifers and for identifying locations that allow the free flow of percolating waters to travel from the surface to an aquifer. Locations where aquitards restrict percolating water from reaching an aquifer limit the need to focus protection efforts on these areas.

Local agencies should at a minimum begin to delineate groundwater recharge areas that meet the minimum standards established by the Water Board for soils with a high permeability rate and aquifers that supply or may potentially supply water for beneficial use. Additional levels of identification and protection may be established at a later time as desired or needed. A tiered approach may be considered for enhancing protection efforts. Establishing additional factors to categorize and protect groundwater recharge

areas should be at the discretion of local agencies. The Water Board can assist the development of additional protection efforts by local agencies by supplying information or identifying information sources. Factors that local agencies should consider when developing a tiered approach to delineating and protecting these location include: a range of permeability rates, aquifer vulnerable to contamination, existing condition of the receiving aquifer, proximity to existing or proposed construction, and depth to underlying aquifer. Incorporating some or all of these factors into delineation and protection efforts will allow local agencies to refine strategies and increase the safeguarding of groundwater supplies. Strategies for identifying groundwater recharge areas within local jurisdictions should use sound information to establish an initial level of protection and then advance protection efforts over time. Protection efforts should not be delayed as complex identification systems are established.

Although local agencies may have a great deal of information already available in-house or easily accessible from websites, they should seek expertise from local hydrologists and geologists to assist with delineating groundwater recharge areas. Specialists from within the Central Coast Hydrologic Region have in-depth knowledge of local conditions and are a valuable resource. Specialists can assist with determining and refining groundwater recharge area criteria and standards and can also assist with developing initial maps and a GIS database. Although acquiring outside assistance will result in additional expenses, relying on specialists will ensure that protection efforts are focused in necessary locations. Third party assistance may also eliminate liabilities or concerns of bias which may exist if the entire process is conducted in-house.

In addition to the two essential criteria noted, a variety of other criterion may be considered by local agencies to narrow down important groundwater recharge areas and focus protection efforts. Although the Water Board may only establish a minimum standard of criteria to identify groundwater recharge areas, local agencies could benefit from establishing additional criteria for classifying these locations. Some criteria have been noted for potentially developing a tiered approach for delineating, but additional criteria may also include: sources of water for infiltration, the function of the aquifer which is being recharged; the areas relationship to the hydrologic cycle, topography, existing vegetation, and the local climate. The criteria that have been noted focus on identifying potential groundwater recharge areas assuming that the land use is undeveloped. As protection strategies are created, consideration should be given to locations where urban development exists along with impervious surfaces. Including a GIS layer of impervious surfaces can be a valuable tool for ensuring that protection strategies are relevant considering existing development.

Protection and Implementation Strategies

The Water Board and local agencies may choose to enter into MOUs that define levels of commitment for protecting groundwater quality, although it is ultimately the responsibility of the local agency to determine what policies and strategies are necessary and implemented within their jurisdiction. As local agencies identify and improve strategies for protecting groundwater quality in groundwater recharge areas, the Water Board may be a valuable resource to assist with the effort.

Local agencies have intimate knowledge in regard to the community's needs, desires, capabilities, and restrictions which are essential considerations in developing strategies for implementation. Groundwater recharge area protection policies are more likely to be implemented and effective if local ownership of the plan exists. A number of different protection strategies are available and worth considering as local agencies advance efforts to protect groundwater recharge areas. Strategies must be selected based on the goals of the jurisdiction developing the plan. No single approach is best for all areas, and there is no panacea for protecting groundwater quality in groundwater recharge areas.

Local agencies should perform an initial review of existing policies to identify what terminology, and protection strategies are already in place. This will also assist in identifying existing regulations that may restrict the implementation of groundwater recharge area protection policies. Existing strategies for the entire county which do not necessarily focus on groundwater recharge areas may be beneficial in protecting groundwater quality. These strategies include: stormwater management, open space protection, riparian buffers, flood control, building guidelines, and general zoning standards. These strategies are typically initiated to achieve a separate purpose and groundwater recharge is usually a co-benefit for the policy. Although the policies often promote the recharge of high quality waters, strategies need to be developed that specifically enhance or maintain recharge in critical groundwater recharge areas. Land use impacts in these locations have a greater effect on groundwater supplies and regional standards should be strengthened in these areas to increase pollution protection and infiltration capabilities.

Local agencies can house groundwater recharge area protection strategies in a variety of planning documents. However, the primary location where goals, policies, and programs should be located at a minimum is in the general plan and local zoning ordinance. The Water Board should encourage local agencies to initially focus on these two documents to establish policies aimed at managing land uses in groundwater recharge areas. The general plan provides the framework in which all local land use decisions must derive and it is essential that it contain policies in regard to groundwater recharge area protection to achieve groundwater quality goals. The zoning ordinance is the primary means of implementing the general plan by classifying the specific land uses that are allowable in zones throughout a local jurisdiction.

The general plan should include the developed standard language for groundwater recharge areas as well as the criteria for identifying these locations. Policies should be developed for mapping or improving the existing maps of these locations. Once groundwater recharge areas are clearly defined and their locations have been mapped then local agencies can develop and implement specific policies focusing on land use strategies for protecting water quality in groundwater recharge areas. Goals and policies should align with the Water Board's stated goals for protecting and improving groundwater quality in the Central Cost Hydrologic Region.

An overview of policy topics that local agencies may incorporate into their general plans are presented in Table 7. Infiltration strategies have been categorized, focusing on open space, stormwater runoff, and development. The matrix also includes policy

considerations in regard to artificial recharge occurring both in-stream and off-stream. Example policies have also been included which were obtained from county planning documents from within the Central Coast Hydrologic Region. The strategies include both regulatory and non-regulatory measures to manage land use activities which is important for consideration to establish a comprehensive program. Information presented in this paper should be considered by local jurisdictions in context to their existing efforts. Furthermore, the information may be beneficial to agencies in the early stages of developing protection strategies for groundwater recharge areas as well as those agencies with established programs.

Table 7: Potential Groundwater Recharge Area Protection Policies

Policy Topic	Description
Reduce Pollutants	
Restrict sources of contamination	<p>Groundwater recharge areas are more susceptible for allowing pollutants to enter into the groundwater system due to the highly permeable soils and geologic characteristics which allow the rapid movement of percolating waters in these locations. Anywhere that a potential pollutant is used, handled, transferred, or stored is a potential source of groundwater contamination. Specific land uses which are known to have the potential of releasing pollutants and contaminating the underlying soils should be restricted from being developed in groundwater recharge areas. Appendix D identifies potential sources of contamination categorized by land use which was developed by the U.S. EPA. This list identifies sources of pollution from land uses that include commercial/industrial, agricultural/rural, residential/municipal, and miscellaneous. Establishing policies to restrict these land uses does not entirely prohibit their development in groundwater recharge areas; however, in order to establish a land use that is a potential source of contamination additional mitigation measures may need to be employed to ensure the safety of groundwater supplies. The types of land uses identified in Appendix E would require a conditional use permit prior to receiving building permits.</p> <p>Example Policies:</p> <ul style="list-style-type: none"> Prohibit any land use in a Primary Groundwater Recharge Area which would allow the percolation of pollutants into the groundwater system. (1) In order to provide greater protection of the aquifers which supply drinking water to the South County, special consideration should be given to the management of contaminants (e.g., hazardous materials, sanitary effluents)

Policy Topic	Description
	in groundwater recharge areas where no protective aquitard layer exists. (2)
Septic system constraints	<p>On-site sewage such as septic systems is a noted source of contamination categorized by land use by the U.S. EPA and it is often necessary to develop specific policy statements to restrict these systems in groundwater recharge areas. On-site waste disposal methods, primarily septic systems and cesspools, rank highest in the total volume of waste water disposed into the ground and they are one of the most common sources of microbial contamination. In addition, leaks in septic systems can create localized areas of extreme contamination. (Kitsap County, 1997)</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Designate those areas having high groundwater conditions, poor soil conditions, and known septic system problems or are primary groundwater recharge areas as shown on maps on file with the Director of Environmental Health as Septic Constraint Areas. (1)
Prohibit dumping in surface waters	<p>Surface water contamination can have a profound impact on groundwater quality particularly in groundwater recharge areas. Some counties have found it necessary to specifically identify the restriction of dumping into creeks in general plan policies to protect groundwater quality. Surface waters which are the primary source for groundwater recharge need to be protected from the introduction of pollutants especially in streams where stream beds are made of alluvium deposits and have high permeability rates.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Prohibit dumping into creek beds and watercourses and require property owners to clean up existing unauthorized dumps. (3)
Prohibit livestock from freely entering surface waters	<p>Livestock operations can have a significant negative impact on stream water quality. All livestock operations and particularly those that raise cattle have the potential to degrade water quality by depositing feces directly into the waterway or on land where stormwater runoff can bring the feces to the stream. In areas of the Central Coast this is a major source of water quality degradation. Policies should be considered for restricting livestock from freely entering surface waterways by providing crossing points, alternative sources of water, and designated hardened access points.</p>
Prioritize cleanup efforts in groundwater recharge areas	<p>Known sources of contamination and sites which need to be cleaned up exist throughout the Central Coast Hydrologic Region. As groundwater recharge areas are identified, sites that are a source of contamination in these areas should receive high priority to focus cleanup efforts. It is not only important to restrict potential sources of pollution from land uses but also to focus efforts on addressing known sources of contamination especially in identified groundwater recharge areas.</p>
Infiltration	
Open Space	
Maintain open space	<p>Maintaining existing open spaces in their natural condition will allow groundwater recharge to occur uninhibited from anthropogenic activities. As plans are established for maintaining and managing open spaces they should focus on designated groundwater recharge areas to ensure that pervious surfaces remain intact and are not disturbed.</p>
Maintain agricultural	<p>Irrigated agriculture increases the volume of deep percolation over that which would occur on native land because the soil column contains residual moisture from</p>

Policy Topic	Description
lands	<p>irrigation during the growing season. If agricultural land is converted to other uses, recharge may be diminished over existing volumes. However, the increased recharge volume of natural recharge that occurs on agricultural land is dependent of irrigation. Agricultural lands provide a benefit to groundwater recharge also simply by allowing a pervious surface to exist that allows natural recharge to occur. Plans to keep agricultural lands in existence in groundwater recharge areas should be considered as well as encouraging urban farms in groundwater recharge areas. The co-benefits associated with agricultural land use are a consideration that should be taken as planning strategies are developed.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Where there is a coincidence of high agricultural productivity and 100-year flood plain groundwater recharge area the land should be retained in agriculture to serve dual open space functions. (3)
Pocket parks	<p>Pocket parks also provide an important land use not only for community members but also for the recharge of groundwater. Particularly in urban environments pocket parks provide a pervious surface which can allow water to infiltrate and percolate to aquifers. Specific park designs which facilitate water infiltration should also be given great consideration.</p>
Acquire lands (easements or fee title)	<p>As development sprawls from centralized cities it is important to ensure that open space is protected for the purpose of allowing natural recharge to occur. Open spaces located within the urban environment also provide an important location for groundwater recharge to occur. As groundwater recharge areas are identified specific lands which provide the main means for groundwater recharge to occur should be protected even if local jurisdictions need to acquire the land. Lands may not always need to be acquired and land easements may also be established to limit development or specific land uses on these properties and maintain the pervious surface.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Identify ground water recharge and watershed lands of highest priority for possible open space acquisition. (2)
Stormwater Runoff	
Stormwater best management practice (BMP)	<p>As identified by the U.S. EPA, there are six minimum control measures for stormwater best management practices which include: public education, public involvement, illicit discharge detection and elimination, construction, post construction, and pollution prevention/good housekeeping. Stormwater BMPs assist in the elimination of pollutants in surface waters that are recharging groundwater supplies and also increase the infiltration of stormwater into the surface of the earth. Detailed manuals exist for establishing and implementing stormwater best management practices and these practices should be focused upon in designated groundwater recharge areas as applicable. Common stormwater BMPs include but are not limited to bioretention, grass swales/filter strips, infiltration trenches, porous pavement, rain barrels, and wet detention ponds. A chart which compares these BMPs to identified design parameters has been included in Appendix E for reference. Low impact development (LID) is the term used to describe land development or re-development that works with nature to manage stormwater.</p> <p>Example Policies:</p> <ul style="list-style-type: none"> In those areas where percolation is the primary means for flood control,

Policy Topic	Description
	implement low impact design (LID) to enhance percolation and allow desirable groundwater recharge to increase supply and minimize seawater intrusion. (4)
Drainage design	<p>Drainage design policies align with general stormwater best management practices; however, local agencies should also give consideration to their local climate when designing stormwater drainage in groundwater recharge areas. Locations that do not receive much annual precipitation should strongly consider not simply focusing on having runoff infiltrate prior to leaving a parcel of land but to guide runoff to on-site retention ponds or dry wells. This approach is likely to increase the volume of recharge that will occur in these locations. The result of directing and concentrating the runoff from a large area into a small area is that the water holding capacity of the soil underlying the disposal area will be exceeded resulting in deep percolation (Feeney, 2010). Consideration should be given to both the retention and detention of runoff to increase surface water infiltration in groundwater recharge areas.</p> <p>Example Policies:</p> <ul style="list-style-type: none"> Require retention of stormwater runoff from impervious surfaces for all new development in Primary Groundwater Recharge Areas through on-site percolation methods so as not to exceed predevelopment runoff levels. Utilize on-site detention methods where percolation methods are not feasible; either system should be designed for a minimum design storm as determined by the County Design Criteria. (1)
Development	
Predevelopment infiltration capabilities	The natural characteristics of lands and their ability to recharge precipitation are drastically altered during development. This occurs due to the introduction of buildings and infrastructure which contain impervious surfaces as well as from the impacts associated with disturbing the natural landscape. Changes to topography and impacting soils with heavy equipment have a significant impact to a parcel of lands ability to recharge groundwater supplies. Identifying the infiltration capability of a parcel of land prior to construction will allow necessary mitigation measures to be included to the construction project to allow post development infiltration capabilities to remain the same as predevelopment capabilities or even provide for improvement.
Grading	Altering undeveloped land by grading can have a drastic impact on an areas ability to recharge groundwater. Efforts should be taken to ensure that the grading of land for development only occurs where it is essential and development should strive to exist with the current landscape to the greatest extent possible. Soils that are compacted and altered topography from grading activities should be mitigated so maintain or improve the preexisting recharge capabilities.
Maintain natural vegetation	Maintaining natural vegetation can improve the amount and quality of infiltration and movement into the groundwater (Yanggen, et al., 1990) Natural vegetation serves to keep permeable soils from eroding and from allowing silt to enter waterways and decrease in-stream recharge capabilities. Vegetation also serves to filter many contaminants found in surface runoff and maintaining its existence can greatly improve the quality of percolating water. Natural vegetation has adapted to survive in the Mediterranean climate of the central coast and non native vegetation may require greater amounts of water in order to survive. These non native plants can place an additional stress on already limited supplies of groundwater. Riparian vegetation and buffers should be included in protection strategies throughout a watershed and especially in groundwater recharge areas.

Policy Topic	Description
	<p>Example Policies:</p> <ul style="list-style-type: none"> Minimize the impacts of public and private development on streams and associated riparian vegetation due to construction, grading, resource extraction, and development near streams. (4) Set back development on public lands and all private development subject to discretionary review a minimum of 50 feet from the top of the bank of any stream or outside the dripline of riparian vegetation, whichever distance is greater. (4)
Housing density	<p>Controlling housing densities is another method of providing open space to allow the recharge process to occur. Regulating the density of development indirectly controls the amount of potential pollutants reaching the groundwater. Housing clusters may be an effective method for regulating housing density in addition to general density provisions such as lot and structure dimensions. Strategic or smart growth principles should be considered throughout a region and particularly in groundwater recharge areas.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Require new parcel sizes to be an average of at least 10 gross acres for parcels with building sites located in primary groundwater recharge areas and allow a maximum average residential density of one dwelling unit per 10 gross acres for parcels which are not divided. Allow exceptions only where the development is: (a) located within the Rural Services Line or within the Urban Services Line; and (b) served by a sewage disposal system operated by a County Service Area or public services district which provides at least secondary treatment with nitrogen removal or which disposes of effluent outside the primary groundwater recharge area. (1)
Impervious / pervious surfaces	<p>Policies should be developed which specifically require impervious surfaces to be reduced and pervious surfaces increased. Increases in urbanization have resulted in increased amounts of impervious surfaces. Changes in the impervious-pervious surface balance causes significant changes to the quality and quantity of surface water runoff and recharge capabilities. Communities recognize the importance of reducing impervious surfaces by restricting development in locations or incorporating pervious surfaces in projects to improve infiltration capabilities.</p> <p>Example Policies:</p> <ul style="list-style-type: none"> Encourage the use of permeable materials in areas where hardscape is proposed. (4) The County shall use discretionary permits to manage construction of impervious surfaces in important groundwater recharge areas in order to protect and manage groundwater as a valuable and limited shared resource. (5)
Stream channel altering	<p>The channelization or introduction of impervious surfaces to streambeds decreases the natural in-stream recharge. This can have a large effect on groundwater quantities and should be avoided.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Discourage the alteration of streams and other natural drainage systems which would affect their appearance, reduce underground water recharge, or cause drainage, erosion or flooding problems. (6)

Policy Topic	Description
Gravel and sand extraction	<p>Mining operations which remove permeable materials can drastically reduce the locations available for recharge. Mining operations need to be reviewed from a regional level to avoid seriously impacting the recharge capabilities in-stream or along stream channels. Mining of alluvial sources can also result in impacts on stream bank stability, channel location and gradient, sedimentation downstream, and groundwater recharge.</p> <p>Example Policy:</p> <ul style="list-style-type: none"> Continually monitor mining operations to determine whether mitigation measures are needed. (3)
Artificial Recharge	
In-stream	Controlled releases from reservoirs and dams allow streams to maintain flowing water year round despite typical seasonal droughts. Maintaining water in stream channels provides an important source of water for groundwater recharge.
Off-stream	<p>Surface water supplies can be redirected to spreading basins or percolation ponds that have highly permeable soils and assist with recharging groundwater supplies. Waste water may be an alternative source of water for recharge if it is treated to a level that will not degrade groundwater supplies and pose a threat to human health. Injection wells are another means of artificially recharging groundwater supplies and sources of water as well as locations for this operation to occur should be considered a potential option for agencies seeking to increase the amount of water recharging aquifers. Local jurisdictions should establish policies that encourage the investigation of potential future locations where off-stream artificial recharge can occur. Any facilities established for the purpose of artificial groundwater recharge should be designed and operated in a manner that is safe for the environment.</p> <p>Example Policies:</p> <ul style="list-style-type: none"> As artificial recharge is critical to sustaining groundwater resources, an analysis of the most effective amount, location, and timing of recharge should be conducted. (2) Use of reclaimed wastewater for landscaping and other uses, including groundwater recharge if adequately treated, should be encouraged and developed to the maximum extent possible. (2) Work with water purveyors and water management agencies to augment natural groundwater recharge where it is environmentally and fiscally acceptable. (1) Runoff retention and recharge facilities shall be properly engineered, and shall be located and operated to minimize adverse environmental impacts. (7)
<p>1 County of Santa Cruz. (1994). General Plan: Conservation and Open Space Element. Retrieved from http://www.sccoplanning.com/html/policy/general_plan.htm</p> <p>2 Santa Clara County. (1994). General Plan: Book B. Retrieved from http://www.sccplanning.org/portal/site/planning/agencychp?path=%2Fv7%2FPlanning%2C%20Office%20of%20%28DEP%29%2FPlans%20%26%20Programs%2FGeneral%20Plan</p> <p>3 San Benito County. (1995). General Plan: Open Space and Conservation Element. Retrieved from http://sanbenitogpu.com/docs.html</p>	

- 4 County of San Luis Obispo. (2010). General Plan: Conservation and Open Space Element. Retrieved from http://www.slocounty.ca.gov/planning/General_Plan__Ordinances_and_Elements/Elements.htm
- 5 Monterey County. (2007). General Plan Draft: Public Service Element. Retrieved from <http://www.co.monterey.ca.us/planning/gpu/draftNov2007/default.htm>
- 6 San Mateo County. General Plan. Retrieved from http://www.sforoundtable.org/P&B/pb_general_plan.html
- 7 County of Santa Barbara. (2010). General Plan: Conservation Element. Retrieved from http://longrange.sbcountyplanning.org/general_plan.php

Source: Author, unless otherwise noted.

All too often, policies are developed but they are never implemented due to a lack of time, money or effort. Simply developing policies to protect groundwater quality and manage land uses in groundwater recharge areas will not be sufficient for achieving the desired goals. An implementation strategy must be firmly in place to ensure that developed policies result in changes to land use decisions in identified groundwater recharge areas. A method that will assist local agencies in ensuring that groundwater recharge areas are being protected as desired is by developing an overlay zone for groundwater recharge areas. A groundwater recharge area overlay zone will allow the implementation of groundwater quality protection efforts to focus in areas where it is needed most. The goal of an overlay zone is to flag concerns in the review process and to make applicants aware of potential hazards or natural resources which may be damaged by unsound development decisions. The designations are not intended to eliminate development, but to assure development mitigates potential problems. Proposals are examined on a case by case basis to ensure that future development will not negatively impact groundwater supplies. This type of zoning is effective for regulating land uses in groundwater recharge areas which typically have boundaries that do not coincide with the existing underlying zoning.

Figure 2: Flow Chart Representing a Typical Planning or Building Permit Approval Process

Figure 2 illustrates the typical planning or building permit approval process for local agencies. Pre-application meetings are an effective method for identifying if a proposed project will be situated in a delineated groundwater recharge area. In this meeting, planners should inform the builder or developer of the additional restrictions which are in place so that design changes or mitigation measures can be implemented in the early stages of the project development. If a pre-application meeting is not conducted, then the

project location can still be investigated during the initial plan review or the department review to ensure that groundwater recharge areas are protected. At this time local agencies will have the opportunity to make certain that proposed land uses comply with policies aimed at protecting water quality and quantity in groundwater recharge areas.

Local agencies should also be proactive in providing information to builders and developers in regard to building requirements in groundwater recharge areas. Maps and relevant policies should be readily available to all interested parties to reduce costly and timely delays to projects that have not incorporated necessary mitigation measures.

Local citizens should also be informed about the designation and delineation of groundwater recharge areas. Citizens should be involved throughout the identification process but for those who are not, they too should be made aware as to why the designations have been made and the benefits associated with managing land uses in groundwater recharge areas. Informing and involving the public in the effort to protect groundwater quality by managing land uses in groundwater recharge areas will promote citizen ownership, and enhance public trust for the project.

Once groundwater recharge area protection policies have been implemented then local agencies should ensure that a monitoring program is developed. Various monitoring strategies will make sure that the desired effects are being achieved; or identify changes that are necessary to improve existing protection efforts and land use regulations. Local agencies should constantly seek to improve and evaluate groundwater recharge area maps to be certain that protection efforts are focused in necessary locations. Groundwater

quality should also continue to be monitored in as many sites as possible to discover if the quality of the resource is being maintained or if surface activities are continuing to cause degradation. The Water Board will be a valuable resource for assisting with groundwater quality monitoring efforts.

A joint effort by the Water Board and local agencies for managing land uses in groundwater recharge areas will assist with improving groundwater quality. Only through continued collaboration will it be possible to achieve a comprehensive regional protection effort for a resource that is essential for the continued development and prosperity of the Central Coast Hydrologic Region. By establishing both internal and external strategies, the Water Board has the opportunity to facilitate a coordinated regional effort to protect groundwater quality.

Conclusion

“Water is the one substance from which the earth can conceal nothing; it sucks out its innermost secrets and brings them to our very lips” (Giraudoux, 1946, n.d.). Maintaining the quality of fresh water supplies is imperative for the continued growth and well being of our communities. In the Central Coast Hydrologic Region where groundwater accounts for 83 percent of the annual supply used for agricultural and urban needs, protection of this resource is paramount. The Water Board is tasked with protecting and maintaining the quality of this resource, and has determined that protection efforts need to be improved in groundwater recharge areas. Addressing water quality issues associated with groundwater recharge areas requires the management of land use; therefore, it is essential that the Water Board coordinate efforts with local planning agencies. The Basin Plan provides the regulatory framework for the Water Board to operate, and it needs to be augmented to facilitate the protection of groundwater recharge areas. The Basin Plan amendment needs to include: the development of standard groundwater recharge area language, criteria for identifying and mapping these locations, and the development of protection strategies. Integrating these elements into the Basin Plan and encouraging local agencies to adhere to minimum standards for protecting groundwater recharge areas will establish regional consistency. Recognizing both internal and external strategies that the Water Board can implement will assist with the management of land uses to restrict pollutants and maintain the natural infiltration capacity of groundwater recharge areas. Protecting the quality of groundwater by increasing protection efforts in groundwater recharge areas will help the Water Board in

achieving its goal that “by 2025, 80 percent of groundwater will be clean, and the remaining 20 percent will exhibit positive trends in key parameters.”

List of Acronyms

BLM	Bureau of Land Management
BMPs	Best Management Practices
Cal Poly	California Polytechnic State University
CCAMP	Central Coast Ambient Monitoring Program
CWA	Clean Water Act
DHS	California Department of Health Services
DWR	California Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GAMA	Groundwater Ambient Monitoring Assessment
GIS	Geographical Information Systems
GWMP	Groundwater Management Plan
IRWMP	Integrated Regional Water Management Plan
LID	Low Impact Development
MOU	Memorandum of Understanding
MWP	Master Water Plan
NGO	Non-Governmental Organization
NPS	Nonpoint Source Pollution
NRCS	Natural Resource Conservation Service
RWQCB	Regional Water Quality Control Board
SDWA	Safe Drinking Water Act
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
UWMP	Urban Water Management Plan
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHPA	Wellhead Protection Areas

Glossary

Adaptive Management in terms of water resource management is a planning and implementation framework that allows ongoing monitoring data to be used to change course, modify policies and direction, and adaptively manage to optimize the value of the resource.

Alluvial of or pertaining to or composed of alluvium.

Alluvium a general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body

of running water, as a sorted or semi sorted sediment in the bed of the stream or on its floodplain or delta, as a cone or fan at the base of a mountain slope.

Anthropogenic of human origin or resulting from human activity.

Aquitard a confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores ground water.

Aquifer a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

Artificial recharge is groundwater recharge that takes place with the assistance of humans. Recharge may occur artificially through injection wells, spreading basins, unlined canals, percolation ponds, management of instream flows, stormwater retention, inefficiencies in water applications, irrigation practices, and the disposal of excess water.

Best Management Practices (BMPs) are schedules of activities, prohibitions or practices, maintenance procedures, and other management practices to prevent or reduce the pollution of “waters of the United States.” BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw materials storage.

Clean Water Act Section 303(d) list refers to Section 303(d) of the 1972 Federal Clean Water Act which requires states to identify waterbodies that do not meet water quality objectives and are not supporting their beneficial uses. Each state must submit an updated list, called the 303(d) list, to the USEPA every two years. In addition to identifying the waterbodies that are not supporting beneficial uses, the list also identifies the pollutant or stressor causing impairment and establishes a priority for developing a control plan to address the impairment.

Confined aquifer an aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined ground water. See artesian aquifer.

Conjunctive use refers to the combined use of surface and groundwater supplies.

Critical recharge areas are groundwater recharge areas that provide the main means of replenishing groundwater. Generally these areas have highly permeable soils that make them favorable for replenishing groundwater but also make them more susceptible to groundwater contamination. These areas typically consist of permeable alluvial materials where there is direct percolation of water into the aquifer.

Evapotranspiration the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Floodplain is the relatively level land area on either side of the banks of a stream regularly subject to flooding. That part of the flood plain subject to a one percent chance of flooding in any given year is designated as an "area of special flood hazard" by the Federal Insurance Administration.

Geographical information systems (GIS) refers to a method of linking a database of information to a precise location on a map.

Groundwater means water located beneath the ground surface in soil pore spaces and in the fractures of rock formations.

Groundwater basin An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

Groundwater overdraft the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions.

Groundwater recharge or replenishment involves pumping or percolating (natural or artificial) storm water runoff or imported water into an aquifer to replenish its supplies.

Groundwater recharge areas are land areas where surface water infiltrates into the ground and contributes to the groundwater stored in an aquifer. Water reaches the saturated zone by way of natural or artificial recharge for the purposes of maintaining ecological processes, future extraction, maintenance of water quality, or halting of seawater intrusion into freshwater aquifers.

Hydraulic conductivity a measure of the capacity for a rock or soil to transmit water; generally has the units of feet/day or cm/sec.

Hydrologic cycle the circulation of water from the ocean through the atmosphere to the land and ultimately back to the ocean.

Impervious surface is a surface that is incapable of being penetrated or passed through; an impermeable surface.

Infiltration the flow of water downward from the land surface into and through the upper soil layers.

Land Use is the occupation or utilization of land or water area for any human activity or any purpose defined in the General Plan.

Low impact development (LID) is the planning and engineering of a site to mimic the natural water cycle functions and watershed relationships. LID can be used to management storm water creatively and with less impact.

Natural Recharge is groundwater recharge that takes place without the assistance of humans. Recharge may occur naturally through rivers, lakes, wetlands, riparian corridors, stream seepage, precipitation, stream inflow, subsurface inflow from up-gradient sources of groundwater, and other water concentrations such as runoff or flooding.

Overdraft see groundwater overdraft.

Permeability the capability of soil or other geologic formations to transmit water. See hydraulic conductivity.

Pollutant is any introduced gas, liquid, or solid that makes a resource unfit for its normal or usual purpose.

Pollution (of water) the alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

Pollution, Nonpoint Source (NPS) means a diffuse discharge of pollutants throughout the natural environment. Nonpoint sources are less definable than point sources and usually cover broad areas of land, such as agricultural runoff.

Pollution, Point Source in reference to water quality, a discrete source from which pollution is generated before it enters receiving waters, such as a sewer outfall, a smokestack, or an industrial waste pipe.

Porosity the ratio of the voids or open spaces in alluvium and rocks to the total volume of the alluvium or rock mass.

Recycled water is municipal and/or industrial wastewater treated to a sufficiently high level that it can be reused.

Saturated zone the zone in which all interconnected openings are filled with water, usually underlying the unsaturated zone.

Seawater barrier is a physical facility, method of operation, or groundwater injection technique designed to prevent the intrusion of saltwater into a body of freshwater.

Seawater intrusion occurs when a groundwater aquifer becomes contaminated by seawater (typically as part of a coastal basin). The seawater flows into the aquifer along a gradient created by excessive pumping where the groundwater surface falls below sea level.

Semi-confined aquifer a semi-confined aquifer or leaky confined aquifer is an aquifer that has aquitards either above or below that allow water to leak into or out of the aquifer depending on the direction of the hydraulic gradient.

Smart growth refers to development that serves the economy, the community, and the environment. Smart growth principles provide guidelines on how and where to accommodate new development. Smart growth principles include 1) mixed land uses; 2) compact building design; 3) walkable neighborhoods; 4) a range of housing opportunities and choices; 5) community and stakeholder collaboration; 6) communities with a sense of place; 7) predictable, fair, and cost-effective development decisions; 8) preservation of open spaces, farmland, natural beauty, and critical environmental areas; 9) a variety of transportation choices; and 10) development directed toward existing communities.

Sole source aquifer areas are recharge areas that contribute water to aquifers that have been certified by the U.S. EPA as “sole-source” aquifers because they contribute at least 50 percent of the supply to a public water system, and for which federal agencies have to exercise special precautions.

Source Control BMP means any schedule of activities, prohibitions of practices, maintenance procedures, managerial practices or operations practices that aim to prevent storm water pollution by reducing the potential for contamination at the source of pollution.

Source Water Protection means preventing pollution of lakes, rivers, streams, and groundwater that serve as drinking water sources. Wellhead protection is an example of source water protection for groundwater. Management of land around a reservoir used for drinking water is an example of source water protection for a surface water supply. Source water protection typically involves the following steps: 1) Delineating source water protection areas; 2) Identifying sources of contamination that may affect the delineated areas; 3) Implementing measures to manage these sources; and 4) Planning for the future.

Stakeholder is a person or group with an interest in the outcome of a policy or decision. Stakeholders typically represent different interests in collaborative policy processes and include those with financial “stakes” as well as those with policy or value interests.

Storm Runoff is surplus surface water generated by rainfall that does not seep into the earth and flows overland to flowing or stagnant bodies of water.

Structural BMP means any structural facility designed and constructed to mitigate the adverse impacts of storm water and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Sustainability of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Total Maximum Daily Load (TMDL) is a means for recommending controls needed to meet water quality standards for a particular waterbody. Establishing a TMDL is an important step in watershed protection because it sets quantified goals for water quality that may then determine what actions are needed to restore or protect the health of a waterbody. More specifically, a TMDL identifies the maximum quantity of a particular pollutant that can be discharged into a waterbody without violating a water quality standard and allocates allowable loading amounts among the identified pollutant sources.

Transmissivity the product of hydraulic conductivity and aquifer thickness; a measure of a volume of water to move through an aquifer. Transmissivity generally has the units of ft/day or gallons per day/foot. Transmissivity is a measure of the sub-surface's ability to transmit groundwater horizontally through its entire saturated thickness and affects the potential yield of wells.

Unconfined aquifer an aquifer which is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.

Unsaturated zone the zone below the land surface in which pore space contains both water and air.

Watershed the land area from which water drains into a stream, river, or reservoir.

Wellhead Protection Areas (WHPA) areas delineated as providing recharge to a drinking water well.

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Appendix A: Stakeholder Contact List

The names and contact numbers of stakeholders have been removed for the publication of this project. Detailed information has been supplied to the Water Board for reference.

Location	Department
Santa Cruz	Staff Hydrologist EHS division Health Service Agency
Santa Cruz	Water Resources Planner EHS division
Santa Cruz	WQ & Water Resources Director EHS division
Santa Cruz	IRWM Contact Regional Water Management Foundation
Santa Cruz	County of Santa Cruz GIS Department
Monterey	Senior Planner County of Monterey
Monterey	Monterey County Water Resource Agency Hydrologist
Monterey	IRWM Contact Greater Monterey County Region
Monterey	Water Resource Engineer IRWM Contact Monterey Peninsula, Carmel Bay, South Monterey Bay
Monterey	Monterey Peninsula Water Management District water resources groundwater
San Luis Obispo	SLO County GIS Department
San Luis Obispo	SLO County Long range planning Resource Management System
San Luis Obispo	SLO County Long range planning Community Planning

Location	Department
San Luis Obispo	SLO County Public Works Environmental Programs
San Luis Obispo	SLO County Water Resources Division of Public Works
San Luis Obispo	SLO County Department of Public Works GIS Department
Santa Barbara	Santa Barbara County Long range planning
Santa Barbara	Santa Barbara County Planning Department
Santa Barbara	SB County GIS Manager
Santa Barbara	Santa Barbara County Public Works Department Water Agency Manager
San Benito	San Benito County Planning Department
San Benito	San Benito County Planning Department GIS Analyst
San Benito	San Benito County Water District
San Mateo	County of San Mateo Planning Department
San Mateo	County of San Mateo Long Range Planning Dept.
San Mateo	County of San Mateo Public Works Department
San Mateo	County of San Mateo Environmental Health Dept.
Santa Clara	Santa Clara County Planning Department Principal Planner
Santa Clara	Santa Clara Valley Water District
Santa Clara	Santa Clara Valley Water District GIS Specialist

Location	Department
Santa Clara	Santa Clara Valley Water District IRWM Contact Pajaro River Watershed
Santa Clara	Santa Clara Valley Water District
Ventura	County of Ventura Planning Division Long range planner
Ventura	County of Ventura Watershed Protection District Groundwater Resources
Ventura	IRWM Contact Watersheds Coalition of Ventura County Government Affairs
Ventura	United Water Conservation District Groundwater Department Manager
State of California / Federal	Senior Engineering Geologist South Central Region Department of Water Resources
State of California / Federal	Supervising Engineering Geologist Southern Region Department of Water Resources
State of California / Federal	Department of Water Resources Map Info
State of California / Federal	Department of Water Resources Southern Region
State of California / Federal	US Bureau of Reclamation Water Resources Planning & Operations Manager
State of California / Federal	US Bureau of Reclamation Mid Pacific Regional Office
State of California / Federal	USGS California Water Science Center Groundwater Specialist CA

Location	Department
State of California / Federal	Manager Ground Water Office (WTR-9) US Environmental Protection Agency
State of California / Federal	Source Water Protection / Sole Source Aquifer US EPA
State of California / Federal	California Coastal Commission Central Coast District Office
State of California / Federal	Department of Fish and Game Central Region
State of California / Federal	DFG Central Region
State of California / Federal	Department of Toxic Substances Control Water Quality Department of Health Services Division of Drinking Water and Environmental Management
State of California / Federal	Department of Toxic Substances Control Annual Groundwater reports Northern California
State of California / Federal	Groundwater Protection Program Department of Pesticide Regulation
State of California / Federal	California Department of Public Health
State of California / Federal	California Department of Public Health
State of California / Federal	USDA National Resources Conservation Services Resource Technology
State of California / Federal	United States Department of Agriculture
Central Coast Hydrologic Region	FUGRO Geologist/Hydrologist Consultant
Central Coast Hydrologic Region	Cleath and Associates Engineering Geologists

Location	Department
Central Coast Hydrologic Region	Geologist/Hydrologist Consultant
Central Coast Hydrologic Region	Balance Hydrologics

Appendix B: Groundwater Recharge Area Definition Table

Source of Definition	Groundwater Recharge Area Definitions and Associated Terminology
Agencies in the Central Coast Hydrologic Region	
County of Santa Cruz	<p>Groundwater recharge areas - areas which by nature of surface soil, slope and subsurface geology are particularly important for allowing surface water to percolate to underground storage.⁶</p> <p>Policy 5.8.1⁷ <u>Primary Groundwater Recharge Area Designation</u></p> <p>Designate on the General Plan Resource Maps those areas where local soil conditions and underlying geologic formations allow for infiltration and percolation of rainfall and runoff into groundwater basins.</p> <p>Primary Groundwater Recharge Zones were defined in the late 1970s as those areas “important for capturing water.”⁸</p> <p>Recharge Zones are regions that provide the primary means of replenishing groundwater stored in aquifers.⁹</p>
San Luis Obispo County	<p>Groundwater recharge or replenishment involves pumping or percolating (natural or artificial) storm water runoff or imported water into an aquifer to replenish its supplies.¹⁰</p> <p>Groundwater Recharge: Any of the approved methods that are designed to detain or slow surface water runoff so that percolation is enhanced.¹¹</p> <p>Recharge areas for the County ground water basins have been identified on the basis of outcrop locations for permeable geologic formations. These geologic formations include stream alluvium and sand dune deposits. The alluvial deposits are in flood plains of creeks and rivers and the sand dune deposits are primarily on the Nipomo Mesa.¹²</p>

⁶ County of Santa Cruz Planning Department. GIS description of Groundwater Recharge Area:

<http://gis.co.santa-cruz.ca.us/internet/Metadata/81.xml>

⁷ County of Santa Cruz General Plan, Chapter 5: Conservation and Open Space Element.

⁸ Santa Cruz County Groundwater Management Plan, 2007, Soquel-Aptos Area. Retrieved from http://www.soquelcreekwater.com/District_Reports_online/GMP-2007/Final_report/FinalDraft-2007_GMP.pdf

⁹ Santa Cruz County Groundwater Management Plan, 2007, Soquel-Aptos Area. Retrieved from http://www.soquelcreekwater.com/District_Reports_online/GMP-2007/Final_report/FinalDraft-2007_GMP.pdf

¹⁰ San Luis Obispo County Water Resources Division of Public Works. Integrated Regional Water Management Plan, July 2007 Plan Update. Retrieved from: <http://www.slocountywater.org/site/Frequent%20Downloads/Integrated%20Regional%20Water%20Management%20Plan/July%202007%20Plan%20Update/pdf/Appendix%20II.pdf>

¹¹ San Luis Obispo County. Conservation Open Space Element, May 2010. Retrieved from: <http://www.slocounty.ca.gov/Assets/PL/Elements/COSE.pdf>

¹² San Luis Obispo County Master Water Plan: Watershed Management. Retrieved from: <http://www.slocountywater.org/site/Frequent%20Downloads/Master%20Water%20Plan/Table%20of%20Contents/pdf/Watershed%20Management.pdf>

Santa Barbara County	<p>Groundwater Recharge: Increases in ground water by natural conditions or by human activity.¹³</p> <p>Recharge is the sum of water entering the aquifer from direct deep percolation of rainfall, seepage from streams and rivers and return flows from irrigation. It is rainfall less losses of evaporation, evapotranspiration, diversion and outflow of the basin.¹⁴</p>
Santa Clara County ¹⁵	<p>Groundwater recharge is categorized as either natural recharge or facility recharge. The District defines “natural” groundwater recharge to be any type of recharge not controlled by the District. Sources may include rainfall, net leakage from pipelines, seepage from surrounding hills, seepage into and out of the groundwater basin, and net irrigation return flows to the basin. Facility recharge consists of controlled and uncontrolled recharge through District facilities, which include about 90 miles of stream channel and 71 offstream recharge ponds. Controlled recharge refers to the active and intentional recharge of the basin by releases from reservoirs or the distribution system. Uncontrolled recharge occurs through District facilities, such as creeks, but refers to recharge that would occur without any action on the part of the District. This includes natural recharge through streams as a result of rainfall and runoff.</p>
Monterey County ¹⁶	<p>Important Groundwater Recharge Areas means floodplains along major streams and rivers.</p>
San Mateo County ¹⁷	<p>Groundwater recharge areas are generally located within stream flood plains where porous gravelly soils facilitate percolation of water from streams. Some percolation also occurs directly from precipitation in stream valleys, especially during periods of heavy rainfall</p>
San Benito County ¹⁸	<p>Sources of natural ground water recharge in the Hollister and San Juan Valleys are infiltration from streams, direct infiltration of rain and subsurface flows from surrounding areas, such as Flint Hills. In the Northern Basins, ground water is derived mainly from rainfall and stream flow. In the San Juan Subbasin, most of the ground water is inflow from areas immediately west of Hollister. Inflow from the San Benito River, rainfall, reclaimed wastewater and deep percolation from applied irrigation water comprise a large portion of this groundwater resource. In the Bolsa Subbasin, recharge from surface sources is by rain and irrigation water that</p>

¹³ Santa Barbara County Comprehensive General Plan. Conservation Element Groundwater Resources Section, May 2009. Retrieved from:

<http://longrange.sbcountyplanning.org/programs/genplanreformat/PDFdocs/ConservationGWRS.pdf>

¹⁴ Santa Barbara County Groundwater Report, 2008. Retrieved from:

https://countyofsb.org/uploadedFiles/pwd/Water/2008%20groundwater%20report%20ver5_CommentsAccepted_Final.pdf

¹⁵ Santa Clara Valley Water District. Urban Water Management Plan 2005 Appendices. Retrieved from:

<http://www.valleywater.org/Services/WaterSupplyPlanning.aspx>

¹⁶ Monterey County General Plan Update Draft, August 11, 2010. Glossary. Retrieved from:

http://www.co.monterey.ca.us/planning/gpu/GPU_2007/Final_PC_Recommendation_Amended_081110/10-Glossary_PC%2008-11-2010_FINAL.pdf

¹⁷ San Mateo County. Vegetative, Water, Fish, and Wildlife Resources Background Issues. Retrieved from: http://www.sforoundtable.org/P&B/gp/GP%20Ch%2001_VWF%26W.pdf

¹⁸ San Benito County. Environmental Resources and Constraints Inventory, 1994. Retrieved from: <http://www.sanbenitogpu.com/pdf/1980GP/SBC-ExistingGP-EnvConst.pdf>

	percolates into the soil. Artificial ground water recharge has a total of two major sources: percolation of captured storm water runoff and imported San Felipe Water.
Ventura County ¹⁹	Groundwater resources are most susceptible to contamination at aquifer recharge areas. Aquifer recharge areas generally have highly permeable soils which can readily pass surface (and subsurface) contamination to the groundwater.
Central Coast Water Board ²⁰	Groundwater recharge (GWR) - Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers. Groundwater recharge includes recharge of surface water underflow.
California State Agencies	
Department of Water Resources ²¹	<p>Recharge area—an area where surface water infiltrates into the ground and reaches a saturated zone in either an unconfined aquifer or a confined aquifer.</p> <p>The recharge area for an unconfined aquifer is the ground surface above the aquifer. The recharge area for a confined aquifer is always some distance away from the area where wells have been built that extract groundwater from the aquifer. In at least one case in California a water district overlies a confined aquifer, but the recharge area for the aquifer lies many miles outside the district's boundaries. In other cases recharge of the confined aquifer may occur only where a stream has eroded through the aquitard into the confined aquifer, allowing recharge to occur through the stream bottom, which is below the aquitard.</p> <p>Discharge area—an area where the groundwater that has been recharged flows out of the aquifer under natural conditions or is removed from the aquifer by wells. In general terms, the Earth consists of recharge areas and discharge areas, which may be either very close together (within meters), or very far apart (many kilometers).</p>
State Water Resources Control Board ²²	Groundwater recharge areas: Areas where water infiltrates into the earth and either increases the total amount of water stored underground or only replenishes the groundwater supply depleted through pumping or natural discharge.
Department of Public Health ²³	Recharge Water - means either recycled municipal wastewater or the combination of recycled municipal wastewater and diluent water that is

¹⁹ Ventura County, General Plan Resources Appendix, 1988. Updated 2010. Retrieved from: http://www.ventura.org/rma/planning/pdf/plans/Resources_Appendix_4-6-10.pdf

²⁰ Central Coast Water Quality Control Plan (Basin Plan), Chapter 2, Beneficial Use Definitions.

²¹ Department of Water Resources California Water Plan Update 2009, Resource management Strategies, Chapter 25 – Recharge Area Protection, Volume 2

²² State Water Resources Control Board. AB 885 On-site Wastewater Treatment Systems Program DEIR. Retrieved from:

http://www.waterboards.ca.gov/water_issues/programs/septic_tanks/docs/draft_eir/10_glossary.pdf

²³ Department of Public Health – Groundwater Recharge Reuse Draft Regulations, August 5, 2008 <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Recharge/DraftRechargeReg2008.pdf>

	<p>applied at a groundwater recharge reuse project (GRRP) facility. (Authority cited: Section 100275, Health and Safety Code and Section 13521, Water Code. Reference: Section 116275(h), Health and Safety Code. Section 60301.685. Recharge Water).</p>
California Department of Health Services ²⁴	<p>The source area for a ground water source includes the recharge area. Recharge areas, which may be natural or artificial, are land areas that contribute water to an aquifer. Recharge occurs naturally from lakes, wetlands, direct precipitation, stream inflow, and subsurface inflow from up-gradient sources of groundwater. Artificial recharge can occur as a result of injection wells and man-made facilities such as spreading grounds, unlined canals, and activities such as irrigation practices. Wells and bore holes can act as conduits to aquifers.</p> <p>The primary recharge area consists of the area with permeable alluvial materials directly overlying an unconfined or semi-confined aquifer, where there is direct percolation of water into the unconfined or semi-confined aquifer. The primary recharge area for a confined aquifer also consists of the permeable materials, but the recharge area may be several or many miles away from the area of the confined aquifer from which extraction takes place.</p> <p>Secondary or upland (i.e., watershed) recharge areas include the land at higher elevations usually consisting of a rock type that is much less permeable than the alluvial materials. Water recharges aquifers from these areas by overland flow of surface water and infiltration from stream flow into fractures in the rock. The groundwater in these fractures may then recharge groundwater in the alluvial aquifers.</p> <p>Recharge areas for fractured rock aquifers are similar to those for porous media, but because flow patterns are typically more complex, recharge area boundaries are more difficult to determine. Fractured rock aquifers can also exist in either confined or unconfined settings. In unconfined or poorly confined conditions, these aquifers can have very high flow (and contaminant transport) rates under rapid recharge conditions such as storm events. Transport times across fractured rock flow systems may be as short as hours to weeks, much more brief than in porous media aquifers.</p> <p>Most types of fractured rock aquifers have proportionally less water storage capacity than porous media aquifers. Bedrock aquifers may still provide significant water supply where the aquifers are part of regional bedrock ground water systems, or whether the aquifers are associated with mountainous areas of high precipitation and recharge. Fractured rock aquifers are characterized by rapid and large rises in the water table during recharge/maximum flow events, and can be influenced by recharge from a large portion of the drainage basin.</p>

²⁴ California Department of Health Services, Division of Drinking Water and Environmental Management. Drinking Water Source Assessment and Protection (DWSAP) Program, January 1999 and Revisions April 1999, and January 2000. Retrieved from: http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWSAPGuidance/DWSAP_document.pdf

Federal Agencies	
US EPA ²⁵	A sole source aquifer (SSA) is an underground water supply designated by the Environmental Protection Agency (EPA) as the "sole or principal" source of drinking water for an area. Based on the statutory language, major criteria to be considered by EPA are whether the aquifer is the sole or principal source of drinking water and whether contamination of the aquifer would create a significant hazard to public health. EPA has further interpreted "sole or principal" to mean that the aquifer must supply at least 50 percent of the drinking water to persons living over the aquifer; there should be no alternate and feasible sources of drinking water that could replace the aquifer. In addition, aquifer boundaries should be delineated based on sound science and the best available information. Petitions may be submitted for entire aquifers, aquifer systems (hydrogeologically connected aquifers), or part of an aquifer, if that part is hydrogeologically separate from the rest of the aquifer.
USGS ²⁶	Recharge (ground water) - The process involved in the absorption and addition of water to the zone of saturation; also, the amount of water added. Recharge area (ground water) - An area within which water infiltrates the ground and reaches the zone of saturation.
Out of State Agencies	
King County, Washington ²⁷	<p>Critical Aquifer Recharge Areas are the geographic areas that have a "critical recharging effect on aquifers used for potable water" (RCW 36.70A.030(5)). Every location within a drainage basin can be designated as either a groundwater recharge or discharge area, and this designation depends upon the direction of groundwater flow within the aquifer. In recharge areas, the flow of groundwater in the saturated zone is directed away from the water table surface while in discharge areas the flow of groundwater is directed toward the water table surface. Near the ground surface of a recharge area flow is directed downward, while a discharge area will have an upward flow near the surface (Freeze and Cherry, 1979). Recharge areas serve to replenish the groundwater supplies, but also allow for introduction of contaminants into the upper most unconfined aquifer. Typically, around 70 to 90 percent of a drainage basin will be a groundwater recharge area (Dingman, 2002).</p> <p>There are five general methods for mapping recharge and discharge areas (Freeze and Cherry, 1979):</p> <ol style="list-style-type: none"> 1) topography (simplest) 2) water levels (piezometric patterns) (most direct) 3) hydrochemical trends 4) environmental isotopes (e.g., tritium, carbon-14) 5) soil and land surface features (vegetation, soil types)

²⁵ United States Environmental Protection Agency. Sole Source Aquifers. Retrieved from: <http://yosemite.epa.gov/r10/water.nsf/2fb9887c3bbafaaf88256b5800609bf0/9fe289eed8753b2e882564de0056ecd2!OpenDocument>

²⁶ United States Geological Survey. Glossary of Hydrologic Terms. Retrieved from: http://or.water.usgs.gov/projs_dir/willgw/glossary.html#R

²⁷ King County, Washington. Executive Report, Best Available Science, Volume 1, February, 2004. Chapter 6: Critical Recharge Areas. Retrieved from: <http://your.kingcounty.gov/ddes/cao/PDFs04ExecProp/BAS-Chap6-04.pdf>

	<p>Recharge areas can be further categorized into several sub-groups based on the function of the water once it enters the aquifer. The main sub-groups that are relevant for the groundwaters of King County include the following:</p> <p>Wellhead protection areas (WHPA): the area delineated as providing recharge to a drinking water well.</p> <p>Sole source aquifer areas: recharge areas that contribute water to aquifers that have been certified by the U.S. EPA as “sole-source” aquifers because they contribute at least 50 percent of the supply to a public water system, and for which federal agencies have to exercise special precautions.</p> <p>Critical Aquifer Recharge Areas (CARAs) in Washington are defined as the geographic areas “where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water” (WAC 365-190-030). All groundwater is potentially vulnerable to contamination. However, existing data on groundwater contamination shows that problems vary spatially and not all regions are equally vulnerable (Merchant, 1994). Effective protection strategies for groundwater, therefore, need to be targeted at the most critical areas.</p>
Hart County, Georgia ²⁸	<p>A recharge area is any portion of the earth's surface where water infiltrates into the ground to replenish an aquifer. The Georgia Department of Natural Resources and the United States Geologic Survey have identified and mapped "significant" groundwater recharge areas and promulgated standards for their protection based on their level of pollution susceptibility. Significant recharge areas are identified based generally on outcrop area, lithology soil type and thickness, slope, density of lithologic contacts, geologic structure, the presence of Karst, and potentiometric surfaces.</p>
Snohomish County, Washington ²⁹	<p>"Critical areas" include areas with a critical recharging effect on aquifers used for potable water.</p> <p>The county has established the following three classifications of critical aquifer recharge areas (CARAs):</p> <p>(1) Sole source aquifers designated by the U.S. Environmental Protection Agency in accordance with the Safe Drinking Water Act of 1974 (Public Law 93-523);</p> <p>(2) Areas within the 10-year travel zone of Group A wellhead protection areas, determined in accordance with delineation methodologies specified by the Washington Department of Health under authority of chapter 246-290 WAC; and</p> <p>(3) Areas of high, medium, and low sensitivity to groundwater contamination, based on depth to groundwater and in accordance with <i>The Ground-Water System and Ground-Water Quality in Western Snohomish County, Washington</i> (United States Geological Survey, Water Resources</p>

²⁸ Hart County, Georgia. Chapter 5 Natural Resources. Retrieved from:

<http://www.hartcountyga.org/compplan/compplan5.htm>

²⁹ Snohomish County, Washington. Retrieved from: <http://apps.leg.wa.gov/rcw/default.aspx?cite=36.70A.030> & http://www.co.snohomish.wa.us/documents/Departments/PDS/Code_Development/Chapter30.62CasadoptedyCouncil.pdf

	Investigations, Report #96-4312, 1997).
Washington State ³⁰	<p>A Critical Aquifer Recharge Area (CARA) is defined by the GMA as “areas with a critical recharging effect on aquifers used for potable water.” The Washington Administrative Code (WAC) <u>Chapter 365-190</u> uses the following definition:</p> <p><i>“Areas with a critical recharging effect on aquifers used for potable water are areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water.”</i></p> <p>Identifying “areas with a critical recharging effect on aquifers used for potable water,” depends on understanding aquifer recharge and what is meant by “a critical recharging effect.”</p> <p>Aquifer recharge occurs where rainfall, snowmelt, infiltration from lakes, wetlands and streams, or irrigation water infiltrates into the ground and adds to the water underground that can supply a well. On the other hand, discharge areas are where ground water is headed toward the ground surface and ultimately flows out from a spring, wetland, stream, lake, estuary, or ocean shore. Wells can also serve as discharge areas, especially larger volume wells, such as those used by municipalities.</p> <p>Most of a watershed is typically a recharge area, with discharge areas occurring to a more limited extent in topographically lower areas. Recharge areas and discharge areas can be mapped using hydrogeologic techniques to determine where ground water is and where it is flowing.</p> <p>Aquifers used for potable water are identified by looking at existing and future planned uses. Existing wells and their protection areas, sole source aquifers, and aquifers otherwise identified as important supplies, are examples of “aquifers used for potable water.”</p> <p>Critical aquifer recharge area maps are delineations of where a community’s groundwater supply meets criteria such as susceptibility, potential for contamination, and priority.</p>
Kitsap County, Washington ³¹	<p>As defined at Section <u>19.150.210</u>, a critical aquifer recharge area means those land areas that contain hydrogeologic conditions that facilitate aquifer recharge and/or transmit contaminants to an underlying aquifer. Critical aquifer recharge areas under this title may be established based on general criteria, specifically designated due to special circumstances, or based on scientific studies and mapping efforts. Factors considered in the identification of critical aquifer recharge areas include depth to water table, presence of highly permeable soils (specifically Group A Hydrologic Soils), presence of flat terrain, and the presence of more permeable surficial geology.</p> <p>A. Category I Critical Aquifer Recharge Areas. Category I critical aquifer recharge areas are those areas where the potential for certain land use activities to adversely affect groundwater is high. Category I critical aquifer recharge areas include:</p>

³⁰ Washington State Department of Ecology: Critical Aquifer Recharge Areas Guidance Document, January 2005. Retrieved from: <http://www.ecy.wa.gov/pubs/0510028.pdf>

³¹ Kitsap County, Washington. Chapter 19.006 Critical Recharge Areas. Retrieved from: <http://www.codepublishing.com/wa/kitsapcounty/html/Kitsap19/Kitsap19600.html>

	<p>1. Areas inside the five-year time of travel zone for Group A water system wells, calculated in accordance with the Washington State Well Head Protection Program.</p> <p>2. Areas inside the ten-year time of travel zones in wellhead protection areas when the well draws its water from an aquifer that is at or above sea level and is overlain by permeable soils without an underlying protective impermeable layer.</p> <p>3. Areas identified as significant recharge areas due to special circumstances or identified in accordance with WAC 365-190-080(2)(c) as aquifer areas of significant potable water supply with susceptibility to groundwater contamination.</p> <p>B. Category II Critical Aquifer Recharge Areas. Category II critical aquifer recharge areas are areas that provide recharge effects to aquifers that are current or potentially will become potable water supplies and are vulnerable to contamination based on the type of land use activity. The general location of these areas is available on the Kitsap County geographic information system. Category II critical aquifer recharge areas include:</p> <p>1. Highly Permeable Soils (Group A Hydrologic Soils). The general location and characteristics of Group A Hydrologic Soils in Kitsap County is given in the Soil Survey of Kitsap County by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). The soil survey information is available on the Kitsap County geographic information system (GIS).</p> <p>2. Areas Above shallow aquifers and/or surface areas which are not separated from the underlying aquifers by an impermeable layer that provides adequate protections from contamination to the aquifer(s) below. The general location of shallow aquifers in Kitsap County is based upon the professional judgment of licensed hydrogeologists with knowledge of the area. The location of shallow aquifers is available on the Kitsap County geographic information system (GIS).</p> <p>3. Areas Above the Vashon Aquifer. Surface areas above the Vashon Aquifer which are not separated from the underlying aquifers by a poorly permeable layer that provides adequate protections to preclude the proposed land use from contaminating the Vashon aquifer below. Vashon aquifers in Kitsap County are typically mapped as "Qva" (Vashon advance aquifer) or "Qvr" (Vashon recessional aquifer) on geologic maps. Best available information concerning the location of Vashon aquifers is available on the Kitsap County geographic information system (GIS).</p> <p>4. Areas with high concentration of potable water supply wells.</p> <p>C. Mapping. Kitsap County, in coordination with water purveyors and other agencies, will produce maps indicating the location of critical aquifer recharge areas.</p> <p>(Ord. 351 (2005) § 34 (part), 2005)</p>
Memphis & Shelby County, Tennessee ³²	Aquifer recharge areas are the points of interchange between surface water and aquifers.
McHenry County, Illinois ³³	Recharge areas are locations where water from precipitation and/or infiltration is transmitted downward to an aquifer area critical for its

³² Memphis & Shelby County, Tennessee. Division of Planning and Development. Retrieved from: http://www.dpdgov.com/Portal/resourcedocs/countygplan_inventorypart1.pdf

³³ McHenry County, Illinois. Groundwater Protection Action Plan. Chapter 1 Groundwater Recharge and Glossary. October, 2009. Retrieved from: <http://www.co.mchenry.il.us/departments/waterresources/Pages/GroundwaterProtectionProgram.aspx>

	<p>recharge1. Discharge areas are areas that are fed by an upward influx of groundwater to the surface. In McHenry County, sensitive aquifer recharge areas are categorized on the Sensitive Aquifer Recharge Area (SARA) map by their potential for groundwater recharge and contamination.</p> <p>Aquifer Recharge Area: is defined by its ability to infiltrate precipitation and runoff and effectively recharge underlying aquifers. A common characteristic of an effective recharge area is the presence of relatively permeable “granular” soils near the surface, underlain by sandy or gravelly deposits. While recharge areas effectively replenish aquifers, the County’s more permeable soils also can lead to groundwater contamination. It is important to note that a very substantial part of the County is underlain by areas that are categorized as having “high potential for aquifer contamination” (SARA map)</p> <p>Groundwater Recharge: For the purpose of this policy, the term recharge refers to the infiltration of water into soil such that it has the potential to recharge an aquifer. It does not reference the recharge of any one specific aquifer. More specifically, recharge is the process by which precipitation reaches and re-supplies the groundwater. Areas that have conditions that favor rapid recharge are the main areas where the groundwater is replenished. Groundwater can be extracted from anywhere, but can only be re-supplied (naturally or artificially) through recharge areas. Therefore, recharge areas provide a fast conduit to re-supply groundwater and counter the effects of human consumptions. On the other hand, the characteristics that encourage rapid refreshment of the groundwater are the same characteristics that favor the travel of contaminants from the surface to the groundwater and which can degrade the groundwater supply. Activities that use materials that might generate contaminants when released to the ground have the potential to cause these contaminants to migrate rapidly to groundwater.</p> <p>Aquifer: means saturated (with groundwater) soils and geologic materials, which are sufficiently permeable to readily yield economically useful quantities of water to wells, springs, or streams under ordinary hydraulic gradients. [35 IL Adm. Code 620.110]</p>
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Appendix C: Basin Plan Amendment Process

TASK	SUBTASK	DELIVERABLE
Research and Development	Baseline Analysis	Advisory group meetings
	Anticipated Degradation	Public scoping meeting
	Establish nexus between groundwater quality and quantity	Technical Report - Existing and anticipated groundwater recharge characteristics
	Evaluate and document existing agency process to protect groundwater recharge areas	Technical Report - Regulatory processes to protect groundwater recharge areas
Staff Report	Existing regulatory conditions to protect groundwater recharge areas	Draft staff report
	Identify potential regulatory alternatives	
	Describe mitigation measures to minimize impacts (CEQA)	
	Develop rationale for selected regulatory process	
	Economic consideration	
	Anti-degradation consideration	
	Necessity determination	
	Modification of water quality objectives	
	Implementation program	
CEQA Checklist	Complete Environmental checklist	Complete CEQA checklist
	Explain any significant impacts due to the implementation of GWRAP	
	Develop mitigation measures program to address any significant impacts	
Draft Basin Plan Amendments	Identify pertinent sections of the Basin Plan	BPA modification reference table
	Make modifications to the identified Basin Plan sections	Strikeout/underline amendment document
Draft Resolution	Gather information necessary to develop attachments	Draft resolution to senior

TASK	SUBTASK	DELIVERABLE
		Draft statement of necessity
		Draft implementation strategy
		Draft groundwater recharge maps
Basin Plan Policy and Amendment Adoption		Prepared adoption package
		Scientific peer review
		Public comment/hearing notice
		Responses to comment
		Water Board adoption hearing
		State Board/OAL adoption
Agency Alignment/BPA Surveillance	Identify existing affected programs	Standard language development
	incorporate revised standards language	Standard language integration
	conduct workshops internal/external	External guidance document development
	develop program surveillance program	Workshop (north)
	biennial reporting	Workshop (central)
		Workshop (south)
		BPA surveillance strategy

Source: Central Coast Regional Water Quality Control Board

Appendix D: Potential Sources of Contamination Categorized by Land Use (U.S. EPA, 2003)³⁴

Commercial/Industrial

Above –ground storage tanks
 Automobile, Body Shops/Repair Shops
 Boat Repair/Refinishing/Marinas
 Cement/Concrete Plants
 Chemical/Petroleum Processing
 Construction/Demolition
 Dry Cleaners/Dry Cleaning
 Dry Goods Manufacturing
 Electrical/Electronic Manufacturing
 Fleet/Trucking/Bus Terminals
 Food Processing
 Funeral Services/Taxidermy
 Furniture Repair/Manufacturing
 Gas Stations
 Hardware/Lumber/Parts Store
 Historic Waste Dumps/Landfills
 Home Manufacturing
 Hydrocarbon Extraction
 Industrial Waste Disposal Wells
 Junk/Scrap/Salvage Yards
 Machine Shops
 Medical/Vet Offices
 Metal Plating/Finishing/Fabricating
 Military Installations
 Mines/Gravel Pits
 Office Building/Complex
 Pipelines (Hazardous Liquid Transmission)
 Photo Processing/Printing
 Synthetic/Plastic Production
 RV/Mini Storage
 Railroad Yards/Maintenance/Fueling Areas
 Research Laboratories
 Retail Operations
 Underground Storage Tanks
 Wood Preserving/Treating
 Wood/Pulp/Paper Processing

Agricultural/Rural

Auction Lots/Boarding Stables
 Animal Feeding Operations/Confined Animal Feeding Operations
 Bird Rookeries/Wildlife feeding/migration zones
 Crops – Irrigated + Non-irrigated
 Dairy Operations
 Drainage Wells
 Lagoons and Liquid Waste Disposal – Agricultural
 Managed Forests/Grass Lands
 Pesticide/Fertilizer Storage Facilities
 Residential Wastewater Lagoons
 Rural Homesteads

Residential/Municipal

Airports (Maintenance/Fueling Areas)
 Apartments and Condominiums
 Camp Grounds/RV Parks
 Cemeteries
 Cesspools – Large Capacity
 Drinking Water Treatment Facilities
 Gas Pipelines
 Golf Courses
 New Development (Addition of impervious surfacing)
 Landfill/Dumps
 Public Buildings
 On-site Sewage (Septic) Systems
 Sewer Lines
 Storm water infiltration basins, Injection into wells (UIC Class V)
 Runoff zones
 Transportation Corridors
 Urban Parks
 Utility Stations
 Waste Transfer/Recycling
 Wastewater Treatment Facilities/Discharge locations
 (incl. land disposal and underground injection of sludge)

Miscellaneous

Abandoned drinking water wells (conduits for contamination)
 Naturally Occurring
 Underground Injection Controls (UIC) Wells
 CLASS I – deep injection of hazardous and non-hazardous wastes into aquifers separated from underground sources of drinking water (banned in Washington)
 CLASS II – deep injection wells of fluids associated with oil/gas production
 CLASS III – re-injection of water/steam into mineral Formations for mineral extraction (banned in Washington)
 CLASS IV – inject hazardous or radioactive waste into or above underground sources of drinking water (banned in US).
 CLASS V – shallow injection wells

³⁴ King County, Washington (2004). Executive Report – Best Available Science, Volume 1. Chapter 6: Critical Aquifer Recharge Areas. Retrieved from <http://your.kingcounty.gov/ddes/cao/PDFs04ExecProp/BAS-Chap6-04.pdf>

Appendix E: Comparison of Stormwater Best Management Practices

Design Parameter	Bioretention	Porous Pavement	Infiltration Trench	Wet Detention Ponds	Grassed Swale/Filter Strip	Rain Barrel
Capitol Cost	\$1.25 per square foot \$5.30 per cubic foot	\$2–\$3 per square foot	\$5 per cubic foot	\$0.50–\$1 per square foot	\$0.25–\$0.70 per square foot	\$0.30–\$4.00 per gallon for tank
Construction Costs	$7.30 \cdot V^{0.999}$	$50,000 \cdot A^{(22)}$	2V–4V (22)	24.5* (Volume in Pond including 10-year storm event) ^{0.705}	\$13,000–\$30,000/acre (type of seed or sod)	\$0.30–\$12 per foot for gutters
Maintenance Costs	moderate (5–7% of construction cost)	low (\$200 per acre per year)	high (5–20% of construction costs)	low (3–5% of construction)	low (5–7% of construction costs) \$350 per acre per year	very low–high (based on water use)
Life Span	5–10 years (soil replacement)	15–20 years	5–15 years	20+ years	25 years	20+ years
Total Phosphorus Removal	65–87%	65%	60%	19–48%	30–99%	low/zero
Total Nitrogen Removal	33–68%	80–85%	60%	31%	20–61%	low/zero
Total Suspended Solids Removal	54–90%	64–95%	90%	61–81%	70–94%	low/zero
Bacteria Removal	≥ 90%	n/a	90%	56–86%	none	low/zero
Organics Removal	90%	n/a	90%	n/a	36–61%	low/zero
Metals	43–97%	95–99%	90%	24–93%	50–93%	low/zero
Biochemical Oxygen Demand Removal	n/a	high	70–80%	n/a	Moderate	low/zero
Oil and Grease Removal	moderate-high	n/a	low-moderate	low-moderate	low-moderate	low/zero

Design Parameter	Bioretention	Porous Pavement	Infiltration Trench	Wet Detention Ponds	Grassed Swale/Filter Strip	Rain Barrel
Treatment of Highly Contaminated Runoff	Yes, if liner is installed	no	no	yes	no	no
Land Area Requirements for Management Practice	large	none	small	very large	large	small
Drainage Area Requirement	variable	none	≤ 5 acres	≥ 10 acres	≤ 2–5 acres	design based
Soil Permeability Requirements	variable based on pollutant components	0.5–3 in/hr	≥ 0.52 in/hr	10 ₅ –10 ₆ cm/s	0.5 in/hr or greater	none
Maximum Flow Velocities	1 ft/s for planted ground cover 3 ft/s for mulch	6-month 24-hour rain event	1-year storm event	100-year storm event	5 cubic feet per second	design based
Maximum Slope	20%	5%	15% surface, 0% trench bottom	15%	2–6%	any
Vegetation	diverse assortment	grasses and other groundcover if desired	none	water tolerant, wetland and aquatic	turf grass, wetland and water tolerant	none
Pretreatment Required	none	none	suspended solids	suspended solids	varies based on design	debris screens and first flush diverter
Use with High Water Tables	no (≥ 6 feet to ground water)	no (≥ 4 feet to ground water)	no (≥ 4 feet to ground water)	yes (if not highly polluted runoff)	yes (2–4 feet to ground water)	yes
Use in Cold Climates	reduced efficiency	limitations concerning snow removal methods	limitations	requires excess planning	yes	yes

Source: (Larson, et al., 2008, p. 132-134)