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21st Street Feature Article

Check out our article featured in Civil Engineering titled “21st Street for the 21st Century”

Civil Engineering

Editor's Note

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INNOVATION is sometimes born of necessity, and this was the case in Paso Robles, California, where drought is a significant problem, as it is throughout that state. Situated in San Luis Obispo County, in the central part of the state, Paso Robles has been grappling with groundwater shortages—a problem that required a sure solution given the fact that the groundwater basin supplies approximately a third of the city's drinking water.

In the process of making improvements to one of the city's key roadways—21st Street—city officials seized upon the opportunity to develop an innovative approach to the roadway project that included bioretention, pervious pavers, landscaped open-channel drainage, and an infiltration trench to cleanse and capture runoff while also minimizing flooding during storms, which had caused problems for both vehicles and pedestrians along 21st Street.

To address the situation, the City of Paso Robles established a partnership with SvR Design Company, of Seattle, and the Central Coast Low Impact Development Initiative—the latter based in San Luis Obispo and established by the state's Central Coast Regional Water Quality Control Board to assist cities and counties within the region design low-impact development projects. Among the primary objectives of the 21st Street Improvement Project were reducing the severity and frequency of street flooding, increasing groundwater recharge, and improving the quality of storm-water runoff that reaches the Salinas River nearby, as well as shading the street with trees, improving bicycle and pedestrian facilities, and reducing traffic speeds by introducing traffic-calming devices.

By upgrading a stretch of 21st Street, the City of Paso Robles, California, improved travel for vehicles and pedestrians and addressed recurring flooding problems.

The project did more than transform one lone street from an impervious, vehicles-only swath of pavement to a multifunctional facility that is welcoming to pedestrians, bicyclists, cars, and commerce. It also spurred the development of "green street" standards that the initiative can now use to help other communities develop their own water-conserving, flood-alleviating streets. And such standards may be sorely needed as communities across California, and indeed throughout the desert Southwest, seek any and all means available to conserve and protect every drop of water they can in the face of a drought that experts say is unprecedented in both severity and longevity.

In short, the 21st Street Improvement Project is a model for other communities faced with similar problems. Not only did it solve the persistent flooding problem along a busy thoroughfare; it also provided a mechanism for cleansing storm water and helping it infiltrate into the ground to supplement the local groundwater supply.

ANNE ELIZABETH POWELL
Editor in Chief

21st Street *for the* 21st Century

In making improvements to a key roadway, the City of Paso Robles, California, implemented measures to retain and treat storm-water runoff and enable it to infiltrate into the ground. The infiltration will recharge groundwater supplies and reduce flooding. By incorporating features for traffic calming, urban development, water quality, and water supply, the 21st Street Improvement Project offers a model for other cities looking to achieve similar objectives. ••••• **By Andy Rowe, P.E., LEED AP, ENV SP, and Larry Kraemer, P.E.**

AS CALIFORNIA ENTERS its fourth year of drought and faces mandatory compliance with the 25 percent overall cutback in water usage ordered in March by Governor Edmund G. Brown, Jr., municipalities throughout the state are scrambling to ensure that they will have enough water to meet current and future demands. For Paso Robles, which is located in central California's San Luis Obispo County, the situation demands careful attention to the local groundwater basin, which supplies roughly a third of the city's drinking water. As part of a recently completed project, Paso Robles combined drainage improvements with storm-water treatment and groundwater recharge. The effort, the 21st Street Improvement Project, is the first of its kind for the city, and it included bioretention, pervious pavers, landscaped open-channel drainage, and an

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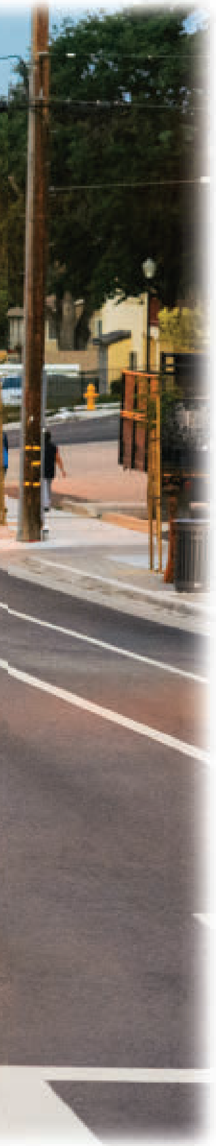


infiltration trench to cleanse and capture runoff while minimizing flooding during storms and preserving the pavement. The newly designed streetscape also improves the overall experience of using the street in that it added trees, traffic-calming features, and bicycle lanes and made the pedestrian walkways more accessible. In a region that is currently experiencing a historic water shortage, the 21st Street design provides a model for flood control, runoff treatment, and groundwater recharge.

Astute storm-water engineering can improve drainage while achieving advanced levels of sustainable urban runoff treatment and groundwater recharge. Recent enhancements to 21st Street in Paso Robles exemplify the potential to combine drainage and recharge improvements. This street was developed on land that once served as a tributary branch of the nearby Salinas River. Past runoff from the surrounding watershed, along with subsequent urban development over several decades, had resulted in frequent flooding, degraded pavement, and inadequate facilities for bicycles and pedestrians. Improvements to 21st Street were necessary to make the street more usable and improve drainage, as well as to recharge the local groundwater supply. In a region that has recently suffered from drastic water shortages, the recharging would be of paramount importance.

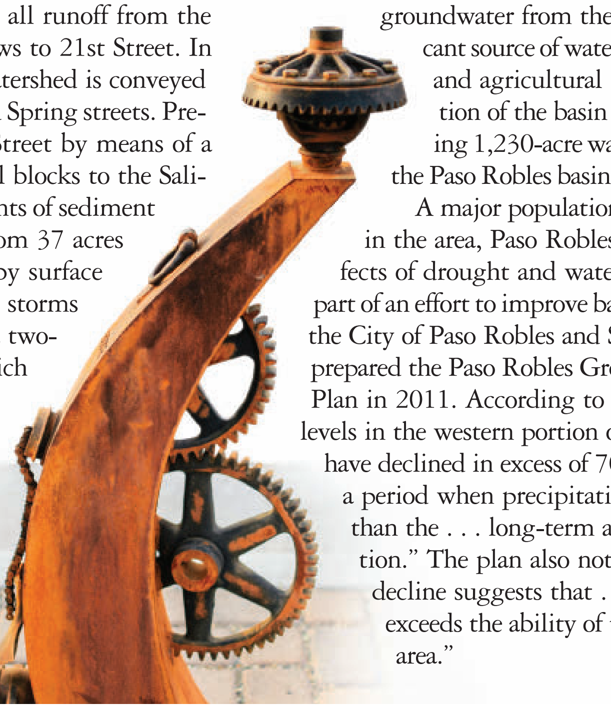
Flooding was a significant problem along 21st Street before the project was undertaken. Complicating matters is the fact that all runoff from the surrounding 1,230-acre watershed flows to 21st Street. In fact, runoff from 1,195 acres of the watershed is conveyed by a pipe to the intersection of 21st and Spring streets. Previously, the water would enter 21st Street by means of a "bubble-up" structure and flow several blocks to the Salinas River, depositing significant amounts of sediment on the roadway. Meanwhile, runoff from 37 acres adjacent to 21st Street would drain by surface flow to the roadway. Thus, even small storms would flood the street. For example, a two-year storm generates flows of 24 cfs, which was enough to impede traffic, overtop the curb line and crossing walkways, and erode landscape areas. After each rain event the already degraded asphalt would sustain more damage, and road edges without curb would further erode. Maintenance problems aside, the frequent flooding posed a safety hazard for vehicles and pedestrians on 21st Street, including commercial areas along the roadway.

To improve the situation, the City of Paso Robles partnered with the integrated design firm SvR Design Company, of Seattle, and the Central Coast Low Impact Development Initiative. The latter, based in San Luis Obispo, California, was established by California's Central Coast Regional Water Quality Board to help cities and counties develop and implement low-impact development projects. Together, the three project participants developed a conceptual design to enhance a critical stretch of 21st Street by incorporating "complete street" and "green street" elements. Designed to facilitate and encourage comfortable travel by pedestrians, bicycles, and motor vehicles, a complete street considers all modes of transportation. Intent upon treating storm water as a resource and not as a waste product, a green street minimizes impervious surface, cleanses urban runoff, and makes it easier for storm water to enter the ground.

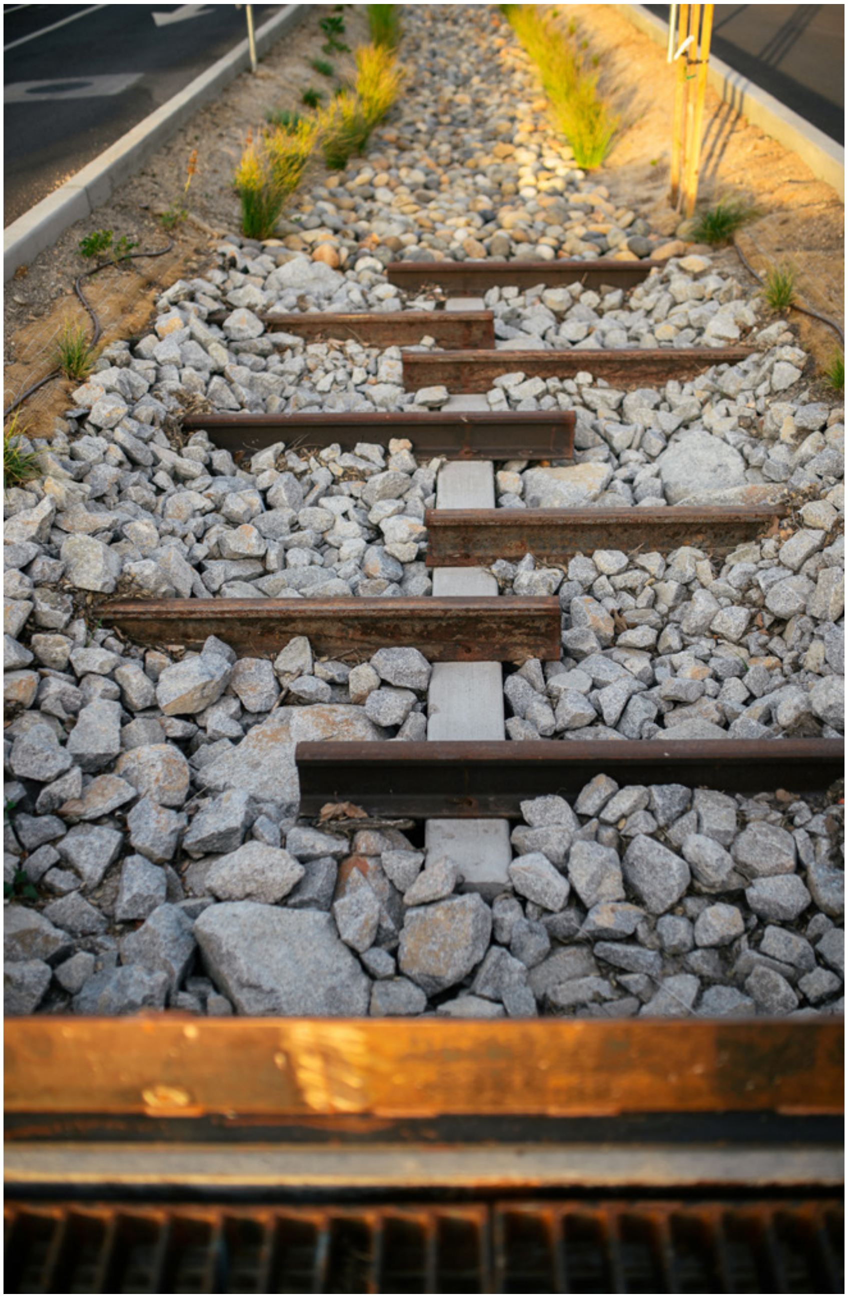
In upgrading a critical stretch of 21st Street, the City of Paso Robles, California, sought to improve travel for all modes of transportation while addressing concerns regarding flooding and storm-water management, *opposite.* Fabricated by a local artist, a bike rack doubles as an eye-catching art installation as part of the upgrades.

The complete street component of the project aimed to shade the street with trees, improve bicycle and pedestrian facilities, promote infill and redevelopment, and reduce traffic speeds by means of traffic-calming devices Drainage and recharge goals included reducing the frequency and severity of street flooding, increasing groundwater recharge, and improving the quality of storm-water runoff reaching the nearby Salinas River. Once the conceptual plan was prepared, the City of Paso Robles hired the engineering firm Cannon, of San Luis Obispo, to prepare the design documents for public bid and to provide construction engineering and management.

In recent decades, the Paso Robles basin, the name given to the water table in the northern portion of San Luis Obispo County, has diminished significantly. Despite the decline, groundwater from the basin remains a significant source of water to meet local municipal and agricultural needs. The western portion of the basin includes the encompassing 1,230-acre watershed, which recharges the Paso Robles basin.



A major population and commercial center in the area, Paso Robles has experienced the effects of drought and water shortage firsthand. As part of an effort to improve basin management locally, the City of Paso Robles and San Luis Obispo County prepared the Paso Robles Groundwater Management Plan in 2011. According to the plan, "Groundwater levels in the western portion of the Paso Robles Basin have declined in excess of 70 feet since 1997 during a period when precipitation was just slightly less than the . . . long-term average annual precipitation." The plan also noted that the "continuing decline suggests that . . . the rate of extraction exceeds the ability of the basin to recharge the area."



The 14 ft wide, 600 ft long open drainage channel that bisects the street along its median is a central feature. Designed to accommodate runoff from the nearly 1,200-acre watershed upstream, the channel can contain the five-year storm event.

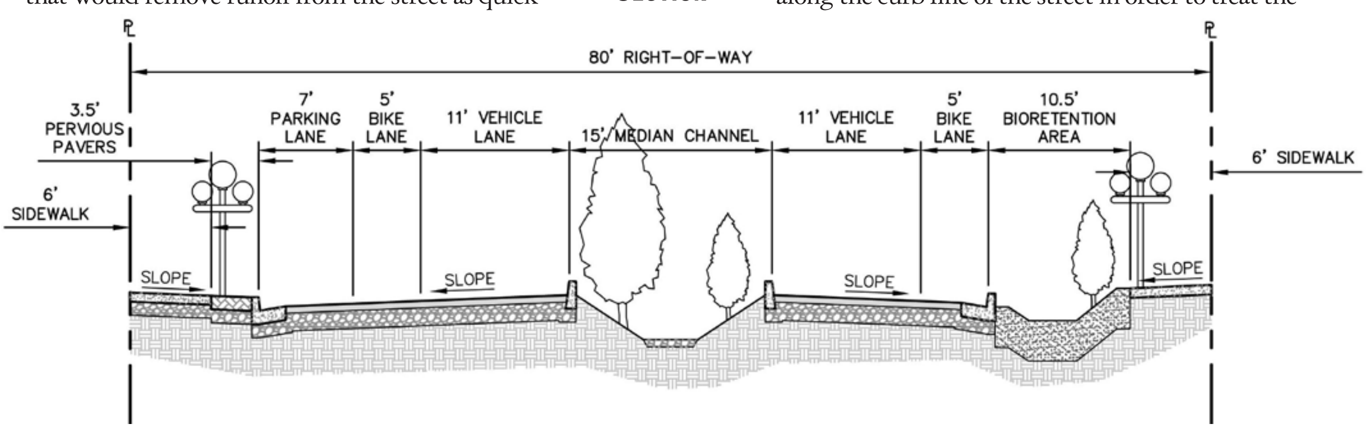
The upgrades to 21st Street were a marked change for Paso Robles. For decades the city had planned and built wide roadways that facilitated vehicular traffic. Vehicles dominated these streets and discouraged people from walking and bicycling. Vast areas of impervious paving had led engineers to design storm drain systems that would remove runoff from the street as quickly as possible. As a result, these streets have limited function.

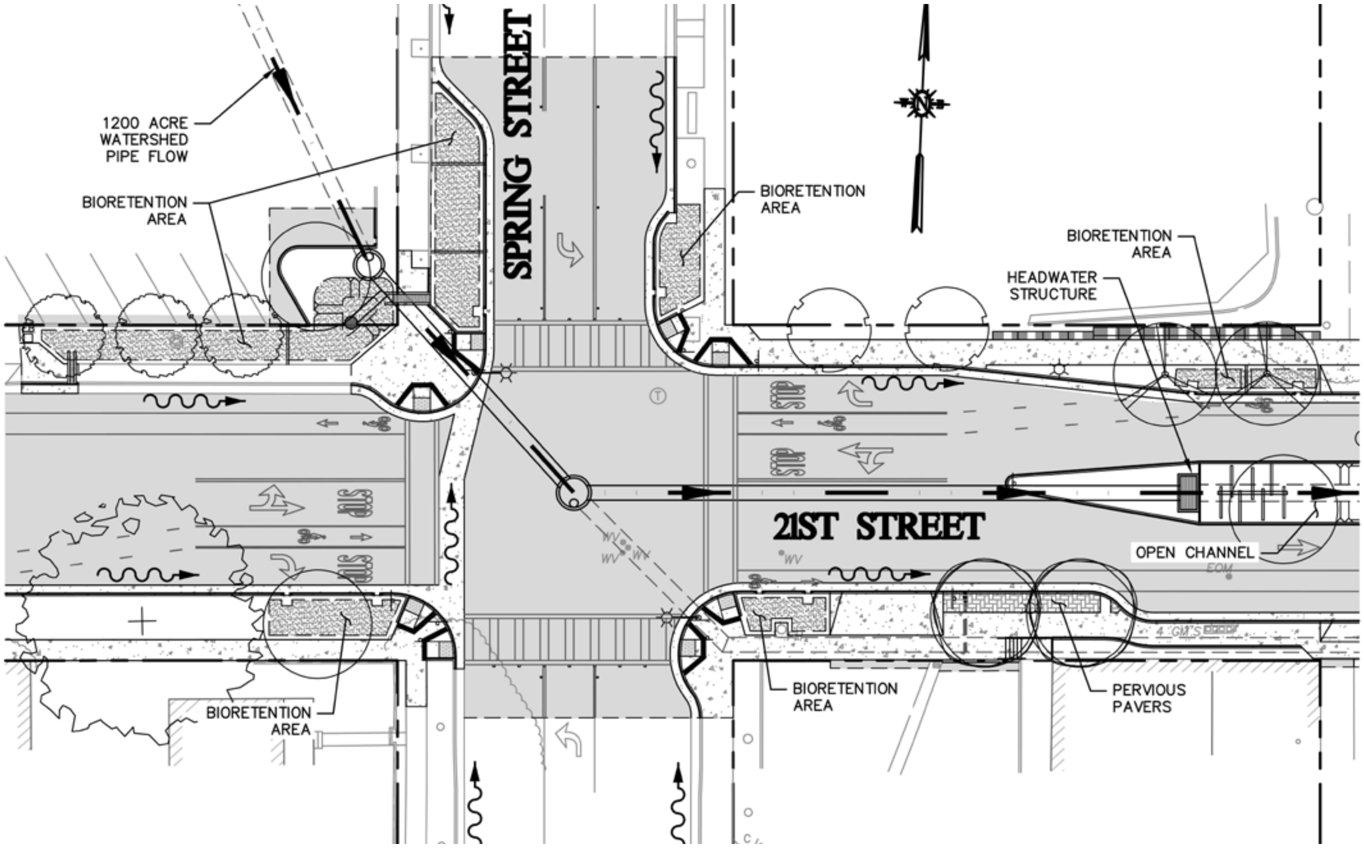
The new 21st Street features a narrower roadway in order to calm traffic and de-emphasize vehicles. The design envisioned a street that would lend itself to multiple functions: walking, bicycling, commerce, community interaction, and control of storm-water runoff. The 21st Street improvements were engineered to combine bioretention to treat the “first flush” of storm water with open-channel flow to convey larger volumes of runoff. Among the project features designed to improve drainage and increase recharge are pervious pavers, bioretention areas, and a 14 ft wide open drainage channel bisecting the street along its median. As a showcase example of a green street, the project offers a template for developing green street standards that could be applied in the future. The Central Coast Low Impact Development Initiative has developed green street standards derived in part from the 21st Street project and has shared them with other municipalities in the region.

Working with SvR, Cannon staff reviewed green street standards in Portland, Oregon, and Seattle to better understand the infrastructure that would be involved. These efforts resulted in the adoption of several design elements intended to ensure that the project will function well over the long term. For example, the use of deepened curbs and impermeable liners will prevent the road base section from becoming saturated and degrading the asphalt. At the same time, depressed gutters and cobble at curb cuts will maintain clear flow paths into the bioretention areas, and check dams will increase ponding volumes. The design team opted not to use filter fabric in bioretention areas because the material has recently been shown to impede infiltration in the long term.

Bioretention areas were placed strategically along the curb line of the street in order to treat the

21st Street Design Cross Section





first flush of storm-water runoff from the 37 urban acres that drain directly to 21st Street. The first flush typically carries the highest levels of pollutants. By comparison, storm water from the larger encompassing watershed is relatively clean. To segregate the polluted urban runoff from nearby streets from the cleaner storm water from upstream, the project directs the urban runoff to the bioretention areas and sends the storm water from the upper watershed to the median channel. In this way the clean water does not mix with and dilute the polluted water, and the bioretention areas are not overwhelmed by the greater volumes of runoff from the larger watershed. The result will be a higher level of pollutant removal in the bioretention areas.

Ranging in size from less than 100 sq ft to more than 1,000 sq ft, the bioretention areas average approximately 300 sq ft. Runoff enters the bioretention areas by means of curb cuts and sidewalk underdrains. Methods developed by the California Department of Transportation for ascertaining water quality volume and flow were used to determine the treatment goals, which are comparable with the 85th percentile storm event. For Paso Robles, such an event amounts to 0.95 in., and the water quality flow rate is 0.18 in. per hour. Based on the results of infiltration tests, some bioretention areas were sized so that the peak water quality flow rate predicted by the California Department of Transportation methods would infiltrate into the ground immediately, while others were designed to capture and store the anticipated treatment volume and allow it to infiltrate into the ground over time.

Providing treatment to the stated goal level for 21st Street itself would not have been difficult. However, because 21st Street funnels storm-water runoff from many blocks to the north and south, attaining the goal was not possible for the entire 37-acre urban surface runoff watershed. When accepting runoff from large tributary areas, the bioretention areas were enlarged to the greatest extent possible given other site characteristics. It is hoped that as streets that contribute runoff to 21st

Designed in part to recharge the local groundwater basin, the 14 ft wide channel has 5 ft wide side slopes and a flat bottom covered in a layer of cobble 6 in. thick.

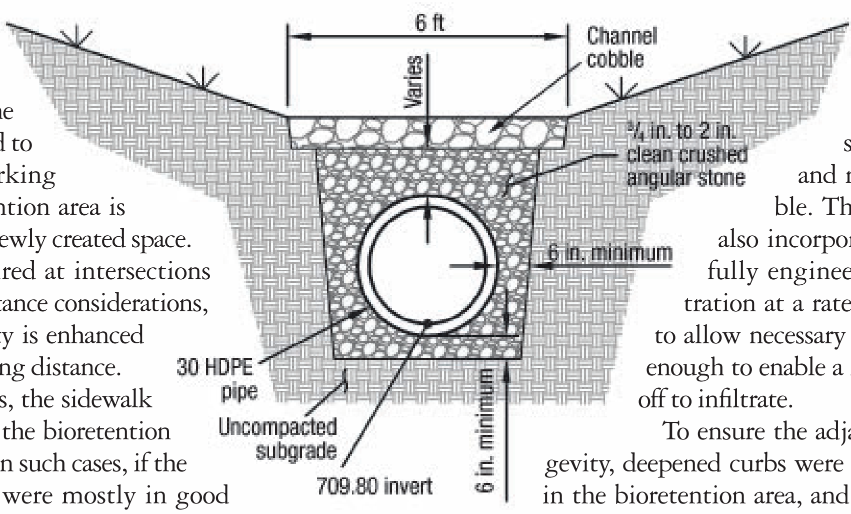
After passing beneath two intersections, the water in the median channel emerges in a separate 170 ft long open channel that is located behind the sidewalk on the north side of 21st Street.

Street are reconstructed in the future, those projects will provide their own treatment to help meet these goals. All told, the newly designed 21st Street has the capacity to treat at least 6,000 cu ft of storm water per storm event.

Bioretention areas were typically located at intersections as part of curb "bulb outs." In such areas, the parking space is removed, the curb line is extended to the edge of the parking lane, and a bioretention area is constructed in the newly created space. Parking is not desired at intersections because of sight distance considerations, and pedestrian safety is enhanced by the shorter crossing distance.

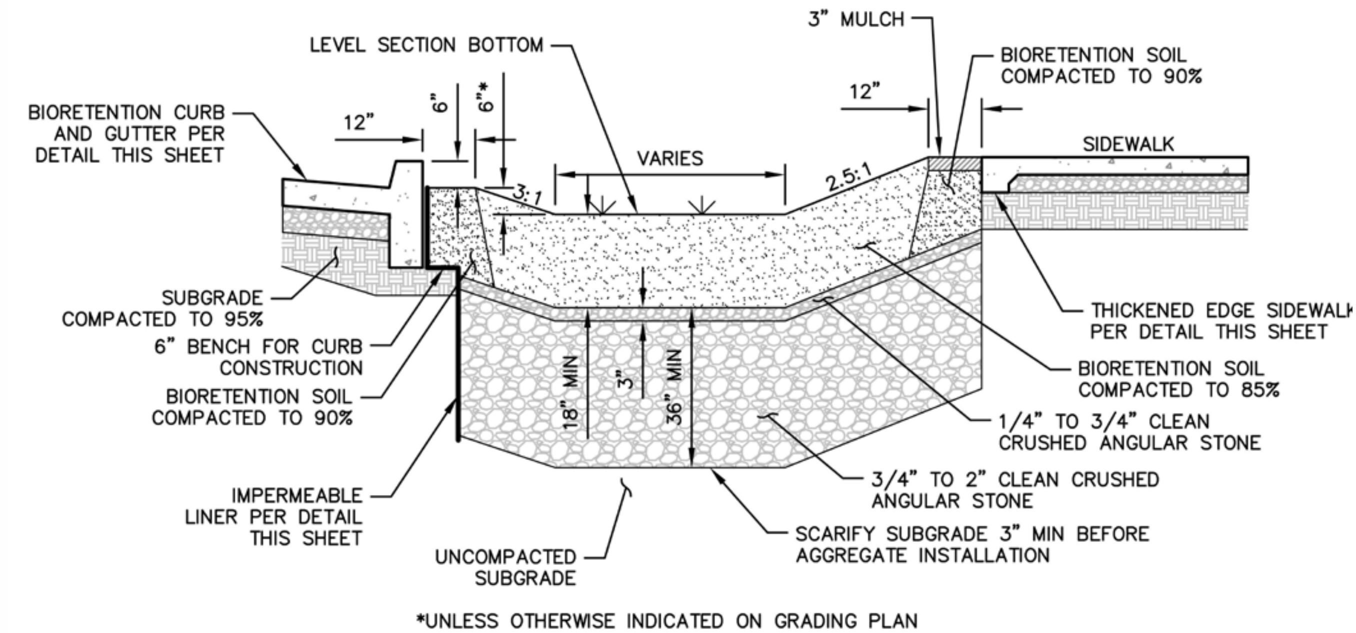
In some locations, the sidewalk is situated between the bioretention area and the street. In such cases, if the existing sidewalks were mostly in good condition, the project provided reverse sidewalk underdrains to route storm water from the curb line to bioretention areas behind the sidewalk. This feature helps preserve existing materials and provides a good solution for retrofit-type designs.

Cannon's research into green street design also led to the application of generous correction factors to the field-tested infiltration results. As a result, once the estimated long-term infiltration rates of the underlying soils were determined, the engineering team had the confidence to design 21st Street for bioretention without underdrains. For bioretention areas designed solely for water treatment and not for groundwater recharge, underdrains are commonly used to prevent storm water from seeping into the underlying soil. For the 21st Street project, the absence of underdrains enables storm water to soak into the ground and reenter the water table. The bioretention areas also incorporate soil mixes carefully engineered to ensure infiltration at a rate that is low enough to allow necessary treatment and high enough to enable a large volume of runoff to infiltrate.



Section of Infiltration Channels

To ensure the adjacent roadway's longevity, deepened curbs were used to retain water in the bioretention area, and impermeable liners were installed between the bioretention areas and the street to prevent saturation of the asphalt base. Trench dams were provided to prevent the saturation of utility trenches and the migration of storm water into utility pipes. For most bioretention areas, overflow was accommodated by means of a curb cut at the downstream end of the facility. Installation of an overflow to an underground storm system was deemed an unnecessary cost as it would have meant the installation of a new



Cross Section of Example Bioretention Design

storm sewer main solely for this purpose. Moreover, storm-water flow for the design storm event does not spread excessively on the roadway now that runoff from the upper watershed is routed to the center median open channel.

In a 2003 document entitled "Protecting Water Quality from Urban Runoff," the U.S. Environmental Protection Agency calls attention to such urban runoff pollutants as sediment, oil, grease from motor vehicles, pesticides and nutrients from lawns, viruses and bacteria from pet waste, and thermal radiation from dark surfaces. These pollutants can harm fish and wildlife, kill vegetation, foul drinking water, and make recreational areas unsafe and unpleasant. The 21st Street project's bioretention design uses soil media, plants, roots, and microbes to achieve the desired pollutant removal and thereby help address water quality issues in the Salinas River.

The top 18 in. of soil within the bioretention areas of 21st Street physically traps particles and strains them out of the storm water. These bioretention systems can achieve a high degree of pollutant removal for the types of urban pollutants mentioned in the U.S. Environmental Protection Agency document. The uppermost layer of mulch and soil in bioretention systems has been found to remove and degrade the largest quantity of pollutants. For example, metals bind easily to the organic matter in the top layer of bioretention soil media. Along with the upper soil levels, drought-tolerant plants in the landscaped areas prevent erosion and treat the storm runoff by means of biological processes. Consequently, treatment and infiltration of the first flush of storm water mean that runoff from 21st Street making its way to the Salinas River is cleaner than it was before.

The 21st Street design also incorporated pervious pavers in pedestrian areas. These concrete pavers were purposely set with gaps between them so that storm water could seep into the ground. Small stones were used to fill the joints between the pavers. In this way the stones enable water to enter the gaps while blocking street litter and other debris.

The inclusion of an open channel in the median of 21st Street will accommodate large-scale storm-water flows from the nearly 1,200-acre watershed upstream. A 42 in. diameter pipe conveying this runoff discharges to an outfall structure located just to the east of the intersection of 21st and Spring streets. The 14 ft wide channel has 5 ft wide side slopes and a flat bottom covered by a 6 in. thick layer of cobble. The median channel extends for nearly 600 ft feet and passes beneath two intersections before crossing under the north side of 21st Street just before the point at which the Union Pacific rail line crosses the road. The water emerges in a new, 170 ft long channel located behind the sidewalk on the north side of 21st Street. At the downstream end of this channel, the water passes through sidewalk underdrains and returns to the curb, where it flows for a few blocks before entering the Salinas River. Although the project did not have the funds necessary to extend the channel all the way to the end of 21st Street, it is hoped that a future undertaking will carry out this task.

The outfall structure to the median channel incorporates a large sump for sediment capture. Energy dissipation features using rock riprap and reclaimed railroad rails are provided at the median outfall and box culvert outfalls. A temporary orifice plate was included to limit flow to the median channel while the vegetation was becoming established. Once the plants are capable of handling the increased flows, this plate will probably be removed.

The five-year event, or 76 cfs, is now contained within the median channel. Used in lieu of drain pipes, this channel enables even more water to infiltrate into the landscape, further augmenting the local water supply. Box culverts facilitate the passage of street traffic at the two intersections under which the channel flows.

In one location, the drainage channel contains an infiltration trench to recharge groundwater supplies even further. The engineering process included infiltration testing aimed at locating areas with the sandiest and, therefore, most permeable soils beneath the streetscape. Placed in these areas of superior infiltration, the trench comprises *(Continued on Page 9)*

21st Street for the 21st Century

(Continued from Page 8) a 100 ft long, 30 in. diameter perforated pipe surrounded by a 42 in. wide section of clean rock. This design allows the storage of large quantities of storm water as it infiltrates into the underlying soil.

The project's bioretention areas can hold more than 6,000 cu ft of storm water at a time. However, an even greater volume will enter the ground during each storm event through the infiltration that will occur in the vegetated drainage channels and the infiltration trench.

The project cost approximately $2.5 million, $1 million of which came from California's Urban Greening Grant Program. Public workshops were held during the planning process, and the feedback obtained in this manner was incorporated into the project design. Construction began in the spring of 2013 and was completed a year later. Raminha Construction, of Atascadero, California, served as the primary contractor on the project.

All told, the 21st Street Improvement Project addresses a chronic flooding problem while also cleansing storm water and helping it infiltrate into the ground to supplement the local groundwater supply. In effect, the project promotes sustainable drainage and groundwater recharge by bringing the original drainage channel into line with its more natural form. Ultimately, the 21st Street Improvement Project is consistent with the larger goals established by California regarding water recycling, water supply storage, and flood control. As a result of the project, groundwater supplies will be replenished to a greater extent, and cleaner runoff will enter the Salinas River, which supports wildlife habitat and provides water for irrigation downstream. The infiltration provided by the project reduces runoff and increases flood protection in an area that has lacked storm-water infrastructure. **CE**

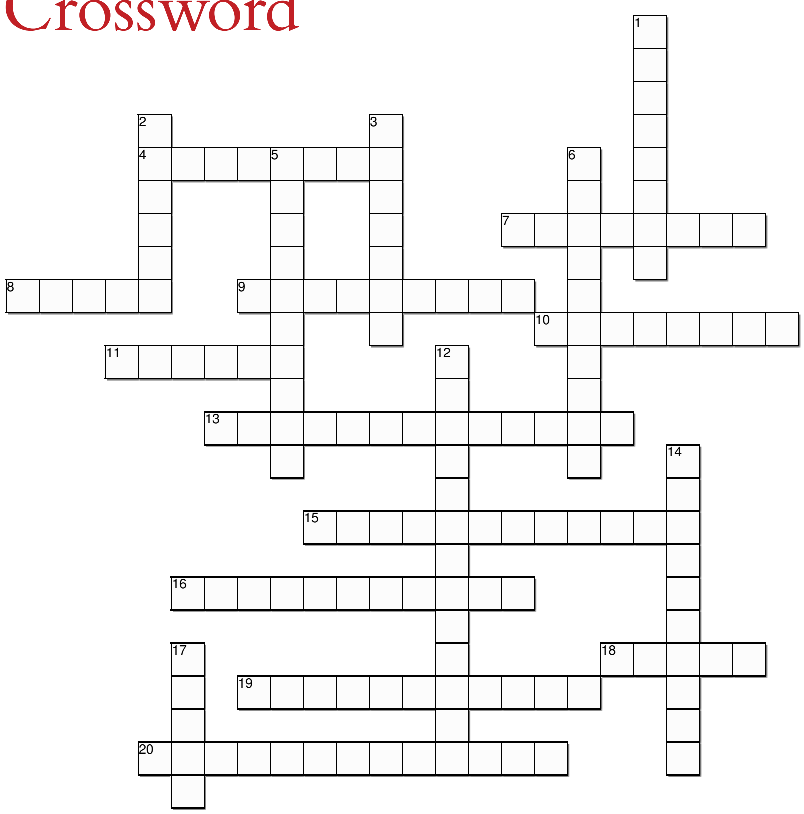

Rowe


Kraemer

Andy Rowe, P.E., LEED AP, ENV SP, is a senior associate engineer at Cannon, an engineering firm based in San Luis Obispo, California, and Larry Kraemer, P.E., is the firm's director of public infrastructure. This article is based on a paper they delivered at the 2014 International Conference on Sustainable Infrastructure, which was sponsored by ASCE and held in Long Beach, California, in November.

PROJECT CREDITS **Owner:** City of Paso Robles, California **Civil engineering, landscape architecture, construction management, and construction engineering:** Cannon, San Luis Obispo, California **Conceptual design and consulting:** SvR Design Company, Seattle **Primary contractor:** Raminha Construction, Atascadero, California **Geotechnical engineer:** Earth Systems Pacific, San Luis Obispo, California **Arborist:** A&T Arborists, Templeton, California

Engineering Terminology Crossword



Across

4. The portion of a regulating valve, which converts mechanical, fluid, thermal, or electrical energy
7. Brand name for a type of liquid which is applied to threads of a bolt and/or nut to secure them
8. Wood-boring tool used by a carpenter to bore holes
9. A polymeric material that may experience large and reversible elastic deformations
10. A colloidal dispersion of one liquid in another
11. A round or cylindrical plug, which is closed at one end and open at the other
13. A solar heating and/or cooling system that requires external mechanical power to move the collected heat
15. Ability of liquid to conduct an electrical current and indicate presence of cations and anions.
16. The lowest region in the earth's atmosphere
18. Manual or power device employing a drum with cable or rope for pulling objects where great power is required
19. Greatest amount of kilowatts needed during a demand interval
20. For a given pressure, temperature at which solid & liquid phases of substance are in equilibrium

Down

1. Equivalent to 1000 watts
2. Friction device sometimes called shock absorber
3. Attractive force exerted by one body on another
5. Expression of total basic anions present in a solution
6. Device used to indicate speed of engine in rpm
12. A hypothetical temperature at which there is total absence of heat
14. Measurement of temperature at extremely low values, i.e., below -200°C
17. The rate of doing work. It is expressed in mass times distance over a period of time

Answers: *Across:* 4. Actuator; 7. Loctite; 8. Auger; 9. Elastomer; 10. Emulsion; 11. Piston; 13. Active System; 15. Conductivity; 16. Troposphere; 18. Winch; 19. Peak Demand; 20. Melting Point *Down:* 1. Kilowatt; 2. Damper; 3. Gravity; 5. Alkalinity; 6. Tachometer; 12. Absolute Zero; 14. Cryogenics; 17. Power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