Excerpts from presentation given at:

Integration of Urban Water Resources and Planning for an Uncertain Future

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XV LATIN AMERICA HIDROGEOLOGY CONGRESS
XXI BRAZILIAN GROUNDWATER CONGRESS
XXII BRAZILIAN MEETING OF WELL DRILLERS
FENÁGUA 2021 NATIONAL WATER TRADE SHOW

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Summary

Urban water resources are currently under a great deal of stress, with increasing urban populations and associated increasing water demands. Climate change is currently happening that exasperates the variability of water supplies, with increased flooding and/or drought conditions. Future conditions are likely to worsen. Current solutions must be robust and be able to handle a wider range of conditions than in the past. Public expectations and perceptions must also change to encourage decision makers and politicians to address these emerging issues and to make suitable changes in their own activities to decrease worsening future conditions.

Urban water solutions require an integrated approach considering stormwater, wastewaters, surface waters, groundwaters, flood control, drinking water, plus aquatic and riparian resources.

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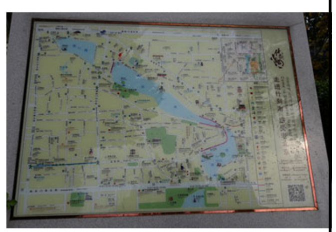
Historical Approaches to Urban Water Management

Initial public works focused on drainage of rain runoff, about 3,000 years ago. The Agora, Athens

Isolated community water supply collection and delivery systems also several thousand years ago. Kamiros, Rhodes

Regional water resources systems about 1,000 years ago. Beijing-Hangzhou Grand Canal



Sanitary wastewater was not collected or treated until about 150 years ago. Wastewater transport to sewage farms, US

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Failing infrastructure with current systems: Infrequent very high flows are channel-forming and may cause severe bank erosion and system damage.

MD and WI DNR photos

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Stormwater Management Approaches must Address a Number of Issues and Objectives

- Stormwater quality treatment started about 50 years ago
- Initial stormwater control focused on runoff flow rate control and local flooding protection.
- Current approaches in stormwater control focus on runoff volume reduction in attempts to match pre-development hydrographs, mainly through infiltration near the source of runoff. Many terms have been used to describe these approaches, including green infrastructure, low impact development, conservation design, smart cities, sustainable drainage systems, etc.

Examples of Small-Scale Stormwater Controls using Groundwater Recharge to Decrease Runoff Volume

Portland, OR, biofiltration around porous paved parking areas

Madison, WI, roof runoff rain garden at residence

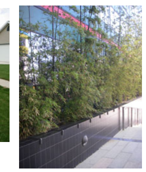
Zurich, porous pavement

Kansas City, MO, curb-cut biofilter

Kansas City, MO, neighborhood "stormwater park" (garden and storage tanks, with infiltration

Cincinnati, OH, large biofilter system at apartments

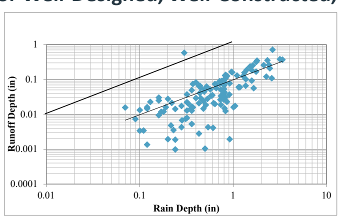
Cross Plains, WI, large grass swale in residential area

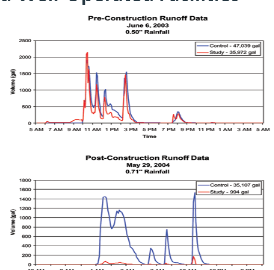


Melbourne, AU, planter box and infiltration chambers

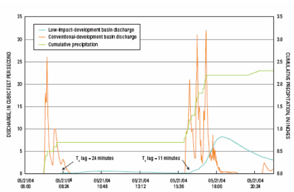
Monitored Performance at Stormwater Infiltration Controls has Shown Outstanding Results for Well-Designed, Well-Constructed, and Well-Operated Facilities

Cincinnati, OH, porous pavement at zoo





Burnsville, MN, rain gardens and biofilters in residential area



Cross Plains, WI, low impact development vs. conventional development

Shown to be effective for up to 25 to 75mm rainfalls for the flows directed to the controls, but difficult to treat all runoff flows in an area. Maximum of about 50% of area treated for retro-fitting in existing large developed areas, can be more for new developments. Regional controls can be more effective.

Problems with Current Approach

- Public expectations of green infrastructure approaches exceed their abilities
  - Limitations on site soils and area available for controls limit their benefits to small and intermediate storms. They are not expected to dramatically reduce floods during rare events. This may only worsen as climate change leads to more highly variable conditions in the future.
- Damage to parts of a non-robust system leads to failures that are expensive and time consuming to correct. More attention needs to be directed to inspections and maintenance
  - Recently, a failure at the Hyperion wastewater treatment facility in Los Angeles (one the largest in the world), due to debris clogging, lead to flooding and destruction of pump systems and parts of the treatment facilities. Hyperion also supplies treated water for beneficial uses (irrigation and toilet flushing) and those users were cut off from their water supplies with little warning and no alternative water sources.
- Potential groundwater contamination may occur with stormwater infiltration.
  - Most municipalities have poor knowledge of the groundwater resources they use for infiltration, which can lead to unanticipated failures and contamination.

Proposed future approaches may not meet expectations

To curb urban flooding, China is building 'sponge cities.' Do they work? July 29, 2021, Christian Science Monitor article

"China's innovative, multi-billion-dollar program to mitigate urban flooding using natural means – by creating "sponge cities" – faced its biggest test yet last week, and showed its limitations.

A sudden, record downpour on July 20 overwhelmed the landlocked central city of Zhengzhou, one of 30 designated sponge cities, causing massive flooding in the subway system and highways, and across the city and surrounding region, as about a year's worth of rain fell in only four days."

People stranded in flood waters along a street following heavy rains in Zhengzhou, China, on July 20 (CNN source)

Photo released by China's Xinhua News Agency, Liulin Township of Suixian County in central China's Hubei Province, Friday, Aug. 13, 2021.

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Potential Contamination of Groundwater and other Effects due to Stormwater Infiltration

- Groundwater contamination potential from infiltrating stormwater is decreased with treatment before discharge to the groundwater, proper media selection, or located in an area having little contamination potential.
- Mounding below infiltration sites can severely reduce infiltration rates
- Increased groundwater recharge may increase groundwater flows to adjacent urban streams.

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Direct Surface Water Connections to Groundwater in Karst Areas (Austin, Texas) (rarely so obvious)

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Potential Problem Stormwater Pollutants Identified using a Weak-Link Model Having the Following Components:

- Their **abundance** in stormwater,
- Their **mobility** through the unsaturated zone above the groundwater, and
- Their **treatability** before discharge.

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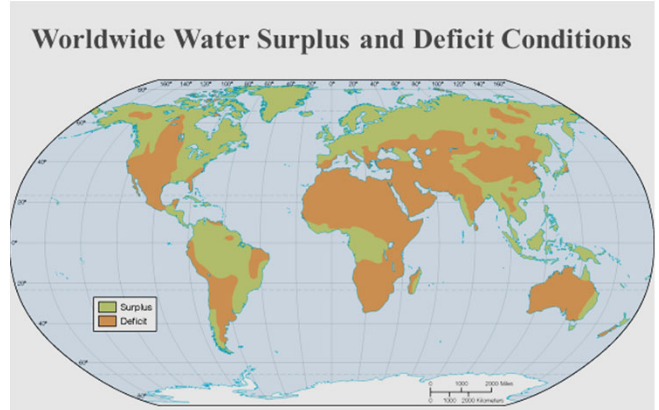
Moderate (regular fonts) to High (bold fonts) Groundwater Contamination Potential from Stormwater Infiltration

Surface Infiltration with no Pretreatment	**Surface Infiltration after Sedimentation Pretreatment**	**Injection after Minimal Pretreatment**
Lindane, chlordane		Lindane, chlordane
Benzo (a) anthracene, bis (2-ethylhexl phthalate), fluoranthene, pentachlorophenol, phenanthrene, pyrene	Fluoranthene, pyrene	**1,3-dichlorobenzene**, benzo (a) anthracene, bis (2-ethylhexl phthalate), **fluoranthene**, pentachlorophenol, phenanthrene, **pyrene**
Enteroviruses	**Enteroviruses**	**Enteroviruses, some bacteria and protozoa**
		Nickel, chromium, lead, **zinc**
Chloride	**Chloride**	**Chloride**



This is an old map and conditions have since worsened with increasing areas having greater water deficits

Stormwater can be a Resource

Ponds and water tanks used for stormwater storage for irrigation and other beneficial uses. Many areas use roof runoff for all domestic needs. Much of the domestic water needs can be met with waters of impaired quality (30% of in-home use, plus most of outside irrigation uses and fire-fighting use).


New Zealand and Australia examples of large roof runoff storage tanks

Findings for Beneficial Uses of Stormwater (from NRC 2015* report)

- Public water supplies are being stressed with increasing populations and diminishing available supplies.
- Beneficial uses of stormwater can replace some of the non-consumptive used of the domestic water supply (especially irrigation and toilet flushing)
- With suitable storage, stormwater can supply most/all of these non-consumptive needs, reducing water demands from the public water supply by significant amounts.
- Availability vs. demand time-series, water quality, necessary treatment, and costs currently restrict the wide-spread use of beneficial use of stormwater.

*NRC (National Research Council), Committee on Beneficial uses of Graywater and Stormwater. National Academy of Science. *Beneficial Uses of Graywater and Stormwater: An Assessment of Risks, Costs, and Benefits.* National Academies Press, Washington, D.C. December 2015.

Findings for Beneficial Uses of Stormwater, NRC 2015 (cont.)

- The safest beneficial uses of stormwater are mainly for purposes having low potentials for human contact, such as irrigation.
- Treatment also is seen to vary from virtually none to very sophisticated water treatment systems. Treatment is generally based on general stormwater pollution control techniques, however, advanced techniques together with disinfection are used if there is a higher potential for human contact.
- Beneficial uses of stormwater are not effectively regulated at this time (most reuse regulations are based on beneficial uses of treated sanitary wastewaters, for example). Given the potential for beneficial uses of stormwater in many areas of the US, higher priority should be given to development of specific guidelines.

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Docklands, downtown Melbourne, Australia showing public sculpture garden in wetland area near large underground tanks.

An example of a large stormwater storage facility for later beneficial uses is at the Docklands Park in Melbourne, Australia. Docklands Park is a downtown open space with an area of 2.7 ha. The park collects stormwater from the adjacent ultra-urban catchment of downtown Melbourne, providing water for park irrigation. The water is directed by gravity or pumped to the Docklands Park underground stormwater storage tanks after passing through three wetlands. Treated stormwater is stored in the underground storage tanks and the captured stormwater is also treated using UV prior to use. The three underground storage tanks have a combined capacity of 500 m^3.

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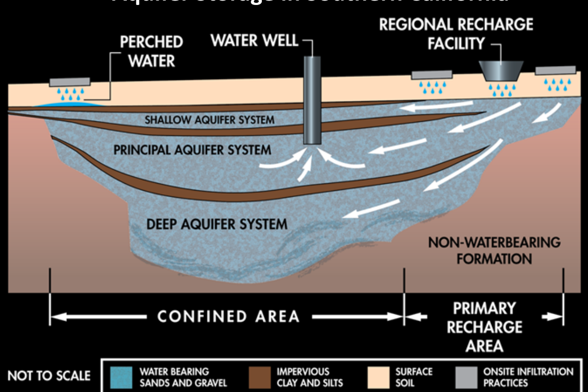
Large-scale Stormwater Infiltration and Injection for Aquifer Storage in Southern California



Source: SCWC Stormwater White Paper

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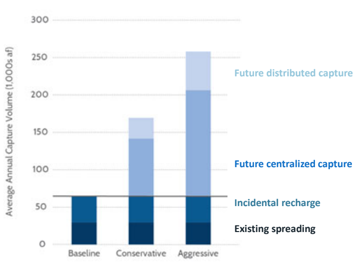
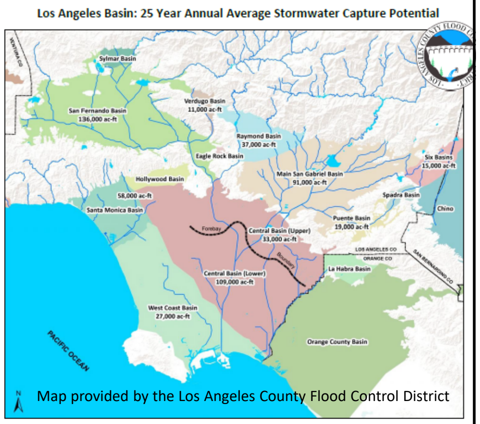
Urban Stormwater Capture and Recharge in Southern California



LA's stormwater capture master plan --- an aggressive path *this century* could add nearly 200,000 afy from today's baseline (SWCMP, 2015)



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Conclusions: Considerations for Urban Water Systems in the Future

- Better site planning to maximize resources of site and to minimize flooding
- Emphasize water conservation and water reuse on site
- Encourage infiltration of runoff at site but prevent groundwater contamination
- Treat water at critical source areas and encourage pollution prevention (no exposed zinc coatings and copper, for example)
- Discourage irrigation of ornamental landscaping with potable water
- Treat runoff that cannot be infiltrated at site
- Consider combined sewers in dense urban areas and treat both stormwater and sanitary wastewater at large regional facilities (requiring large runoff storage facilities and supplemental intermittent treatment processes)
- Consider regional storage and recharge for seasonal and future water needs
- Provide primary and secondary drainage systems for water that cannot be infiltrated or used on site and better planning to minimize flood damage