Urban Subsurface Drainage



AMERICAN SOCIETY OF CIVIL ENGINEERS

Urban Subsurface Drainage

Prepared by the Urban Drainage Standards Committee, Codes and Standards Activities Committee (CSAC), Technical Activities Committee (TAC), ASCE

> Approved by Agricultural Drainage and Urban Subsurface Water Management Committee and the Water Resources Engineering Division, ASCE

> > Published by

ASCE American Society of Civil Engineers

1801 Alexander Bell Drive Reston, Virginia 20191-4400 Abstract: Urban Subsurface Drainage, ASCE Manuals and Reports on Engineering Practice No. 95, was prepared by the Urban Drainage Standards Committee, Water Resources Standards Council, Codes and Standards Activities Committee, and Technical Activities Committee of the American Society of Civil Engineers. This manual provides guidance in the planning, design, construction, and operation and maintenance of urban subsurface drainage systems. Within this framework, the manual discusses such topics as: 1) system configuration including collection system components; 2) hydraulics and hydrology; 3) drain envelopes; 4) loads and pipe behavior; 5) pipe materials; 6) contract documents, codes, and permits; 7) installation methods; and 8) operation and maintenance plan development. Engineers should use this manual of practice as a complement to three standards (ANSI/ASCE 12–92, Standard Guidelines for Design of Urban Subsurface Drainage; ASCE 13–93, Standard Guidelines for Installation of Urban Subsurface Drainage; and ASCE 14–93, Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage) previously developed by the same committee.

Library of Congress Cataloging-in-Publication Data

Urban subsurface drainage / prepared by the Urban Drainage Standards Committee, Codes and Standards Activities Committee (CSAC), Technical Activities Committee (TAC), ASCE.

p. cm.—(ASCE manuals and reports on engineering practice; no. 95) Includes bibliographical references and index.

ISBN 0-7844-0323-6

1. Subsurface drainage—Handbooks, manuals, etc. 2. Sewerage—Design and construction—Handbooks, manuals, etc. 3. Sewerage—Maintenance and repair—Handbooks, manuals, etc. I. American Society of Civil Engineers. Urban Drainage Standards Committee. II. American Society of Civil Engineers. Codes and Standards Activities Committee. III. American Society of Civil Engineers. Technical Activities Committee. IV. Series.

TC970.U73 1998

628'.21-dc21

98-25673

CIP

The material presented in this publication has been prepared in accordance with generally recognized engineering principles and practices, and is for general information only. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application.

The contents of this publication are not intended to be and should not be construed to be a standard of the American Society of Civil Engineers (ASCE) and are not intended for use as a reference in purchase of specifications, contracts, regulations, statutes, or any other legal document.

No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE.

ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefore.

Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

Photocopies: Authorization to photocopy material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by ASCE to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$8.00 per chapter plus \$.50 per page is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923. The identification for ASCE Books is 0-7844-0323-6/98/\$8.00 + \$.50 per page. Requests for special permission or bulk copying should be addressed to Permissions & Copyright Department, ASCE.

Copyright © 1998 by the American Society of Civil Engineers. All Rights Reserved. Library of Congress Catalog Card No: 98-25673 ISBN 0-7844-0323-6 Manufactured in the United States of America

MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his everyday work, rather than the findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however; nor is it so elementary or so conclusive as to provide a "rule of thumb" for non-engineers.

Furthermore, material in this series, in distinction from a paper (which expressed only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each work shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, in order that its merit may be definitely understood.

In February 1962 (and revised in April 1982) the Board of Direction voted to establish:

A series entitled "Manuals and Reports on Engineering Practice," to include the Manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such Manual or Report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past Manuals. Numbering would be consecutive and would be a continuation of present Manual numbers. In some cases of reports of joint committees, bypassing of Journal publications may be authorized.

MANUALS AND REPORTS OF ENGINEERING PRACTICE

No.	Title	No.	Title
13	Filtering Materials for Sewage	69	Sulfide in Wastewater Collection and
	Treatment Plants		Treatment Systems
14	Accommodation of Utility Plant	70	Evapotranspiration and Irrigation
	Within the Rights-of-Way of Urban		Water Requirements
	Streets and Highways	71	Agricultural Salinity Assessment and
34	Definitions of Surveying and		Management
	Associated Terms	72	Design of Steel Transmission Pole
35	A List of Translations of Foreign		Structures
	Literature on Hydraulics	73	Quality in the Constructed Project: A
37	Design and Construction of Sanitary		Guide for Owners, Designers, and
	and Storm Sewers		Constructors
40	Ground Water Management	74	Guidelines for Electrical
41	Plastic Design in Steel: A Guide and		Transmission Line Structural
	Commentary		Loading
45	Consulting Engineering: A Guide for	75	Right-of-Way Surveying
	the Engagement of Engineering	76	Design of Municipal Wastewater
	Services		Treatment Plants
46	Pipeline Route Selection for Rural	77	Design and Construction of Urban
	and Cross-Country Pipelines		Stormwater Management Systems
47	Selected Abstracts on Structural	78	Structural Fire Protection
	Applications of Plastics	79	Steel Penstocks
49	Urban Planning Guide	80	Ship Channel Design
50	Planning and Design Guidelines for	81	Guidelines for Cloud Seeding to
	Small Craft Harbors		Augment Precipitation
51	Survey of Current Structural	82	Odor Control in Wastewater
	Research	0.5	Treatment Plants
52	Guide for the Design of Steel	83	Environmental Site Investigation
	Transmission Towers	84	Mechanical Connections in Wood
53	Criteria for Maintenance of	0=	Structures
E 1	Multilane Highways	85 84	Quality of Ground Water
54 55	Sedimentation Engineering	86	Operation and Maintenance of Ground Water Facilities
55	Guide to Employment Conditions for Civil Engineers	87	Urban Runoff Quality Manual
57		88	Management of Water Treatment
5/	Management, Operation and Maintenance of Irrigation and	00	· Plant Residuals
	Drainage Systems	89	Pipeline Crossings
59	Computer Pricing Practices	90	Guide to Structural Optimization
60	Gravity Sanitary Sewer Design and	91	Design of Guyed Electrical
00	Construction	, ,	Transmission Structures
62	Existing Sewer Evaluation and	92	Manhole Inspection and
-	Rehabilitation		Rehabilitation
63	Structural Plastics Design Manual	93	Crane Safety on Construction Sites
64	Manual on Engineering Surveying	94	Inland Navigation: Locks, Dams, and
65	Construction Cost Control		Channels
66	Structural Plastics Selection Manual	95	Urban Subsurface Drainage
67	Wind Tunnel Model Studies of		-
	Buildings and Structures		
68	Aeration: A Wastewater Treatment		
	Process		

Process

TABLE OF CONTENTS

1 INTRODUCTION General Scope 2 PLANNING Introduction Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites Wick Drains	xi
General Scope 2 PLANNING Introduction Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints. Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	. 1
Scope 2 PLANNING Introduction Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
PLANNING Introduction Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints. Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Introduction Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	2
Site Analysis Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	3
Determine Information and Data Required Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	3
Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	3
Review Available Data Determine Environmental and Political Constraints Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	3
Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Reconnaissance Survey and Preliminary Investigation Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	6
Evaluate the Data Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Technical Studies and Additional Data Needs Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Alternative Considerations Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Recommended Plan References. 3 SYSTEM CONFIGURATION Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	8
3 SYSTEM CONFIGURATION. Introduction. Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	8
Introduction Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Collection System Components Pipes Aggregates Geotextiles Geocomposites	
Pipes	11
Pipes	11
Aggregates	12
Geocomposites	12
	12
Wick Drains	12
	12
Geomembranes	12
Conveyance and Outlet	13
Applications	
Foundation Drains	
Roads, Airports, and Other Pavements	13
Pervious and Impervious Surfaces	
Unpaved Areas	

	Appurtenances	18
	Pumping Stations	18
	Vaults	19
	Manholes	19
	Cleanouts	20
	Environmental	
	Corrosion	
	Encrustation.	
	Economics	
	References	
	References	
4	HYDRAULICS AND HYDROLOGY	25
_	Introduction	
	Water Sources	25
	Subsurface Water	
	Surface Water	
	Subsurface Drainage Considerations	
	Soil Permeability	<u>2</u> 0
	Final cost in a Cost Direction	∠0
	Evaluating Soil Profiles	
	Drainage Requirements for Vegetated Areas	20
	Special Requirements for Paved Surfaces	
	Subsurface Drainage Theory	
	Drainable Versus Nondrainable Groundwater	
	Drainage Formulae and Recommended Practices	
	Steady-State Flow	
	Non-Steady-State (Transient) Flow	
	Common Subsurface Drainage Applications	44
	Groundwater Removal with Relief Drains	
	Seepage Control with Interceptor Drains	45
	Water Control Beneath Pavement Structural Sections	47
	Inflow-Outflow Continuity	
	Flow Continuity for Maximum Performance	49
	Determining Inflow to Collectors	50
	Hydraulics of Subsurface Drains	54
	References	58
5	DRAIN ENVELOPES	61
	Introduction	61
	Drain Envelope Materials	63
	Gravel	63
	Organic Material—General	63
	Glass Fiber	. 64
	Prewrapped Loose Materials	65
	Prewrapped Geotextiles	
	Principles of Drain Envelope Design.	د ده ۵۸
	Exit Gradients in Soil Near Drains.	دن ۱۰
	Hydraulic Failure Gradient.	09
		/U

CONTENTS	vi

	Design of Drain Envelopes	73
	Gravel Filter Envelope Design	73
	Gravel Hydraulic Envelope Design	74
	Geotextile Filter Envelope Design	76
	Prewrapped Loose Material Filter Envelope Design	78
	Combination Gravel and Geotextile Filter Envelope Design	79
	Installation of Drain Envelopes	80
	Drain Filter Envelopes	80
	Gravel Drain Envelopes	
	Envelope Thickness	83
	References	84
6	STRUCTURAL DESIGN	87
	Introduction	
	Loads	
	Dead Loads	
	Soil Loads	
	Pipe Weight	
	Internal Fluid Weight	88
	Foundation Loads	
	Surcharge Loads	88
	Live Loads.	89
	Highway Loading	
	Construction Vehicles	
	Train Loads	
	Aircraft Loads	
	General Pipe Behavior	
	Rigid Pipe Design	
	Concrete Pipe Design	
	Flexible Pipe Design	
	Corrugated Steel Pipe Design.	
	Plastic Pipe Design	
	Structural Design of Geocomposite Subsurface Drains	
	References.	
7	MATERIALS	111
	General	
	Pipe	111
	Concrete Pipe	112
	Thermoplastic Pipe	
	High Density Polyethylene (HDPE) Pipe	114
	Poly(vinyl chloride) (PVC) Pipe	
	Acrylonitrile-Butadiene-Styrene (ABS) Pipe and ABS Composite	
	Pipe	116
	Metal Pipe	
	Vitrified Clay Pipe (VCP)	
	Other Materials and Products.	

8	CONSTRUCTION	
	General	119
	Contract Documents	119
	Codes and Permits	120
	Site Inspection	120
	Pipe and Geocomposite Subsurface Drain Installation Methods	120
	Open Trench Unsupported	
	Open Trench Supported	121
	Trenching Machines	
	Plow or Trenchless Drain Laying Machines	
	Special Considerations During Installation	130
	Grade Control	130
	Trench Widths	
	Backfill	
	Pipe Stretch	
	Drain Envelopes	
	Geocomposite Exterior Coverings	
	Separated Joints	
	Curves	
	Construction Loads	
	Pavement Considerations	
	Dewatering	
	Outlet Placement	
	Safety	
	Inspection	
	Acceptance	
	References.	
	Total Control of the	
9	OPERATION AND MAINTENANCE	143
•	Introduction	
	Operation and Maintenance Plan	
	Scope	
	Responsibilities	
	Design Criteria.	
	Normal Operating Procedures	
	Abnormal Operating Procedures	
	Preventive Maintenance Procedures	145
	System Appurtenances	146
	Safety	
	Drainage Performance	
	Detection of Poor Drainage System Performance	
	First Steps	150
	Action	150
	Drain Repair and Restoration.	150
	Recommendations and Conclusions	153
	Water Quality.	
	Monitoring and Record Keeping.	155
	Preventive/Corrective Measures	155
	2 10 VEHILIVE/COHECHIVE IVIEASURES	158

Inspection	158
Open Drain Systems	
Pipe Drain Systems	
Geosynthetics and Geofabrics	
Monitoring and Record Keeping	
Typical Trouble Signs	
Maintenance	
Basic Requirements	164
Materials	164
Equipment	164
Methods and Procedures	167
Safety	169
References	
GLOSSARY	171
INDEX	175