
FOUNDATION PERFORMANCE ASSOCIATION
DRAINAGE GUIDELINES
Document no: FPA-SC-17-0
Developed by: FPA Structural Committee
Chairs: Main Committee - Ron Kelm, P.E.
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Subcommittee: Dan Jaggers, Michael Skoller, Kumar Arya, Gary Beck, Nicole Wylie, Ron Kelm, Francisco Carrillo, Mike Qaddumi
Presented to : Foundation Performance Association
Presented by: Gerard J. Duhon, P.E.
Presented on: 14 March 2012

WHO WAS INVOLVED?

Francisco Carrillo, Mike Qaddumi, Michael Skoller – Knowledge of design of drainage systems

Kumar Arya – Knowledge of infrastructure

Gary Beck – Knowledge of drainage system design and environmental construction methods

Dan Jaggers – Contracting experience, plumbing knowledge, drainage problem solving

Ron Kelm, Nicole Wylie – Knowledge of drainage effects on foundations, soils, organization of document

Gerard Duhon – Wrote rough draft of most sections of paper, performed research

Mike Qaddumi – Provided conference room at Interfield for work on document

Ed Fronapfel, Toshi Nobe, Steve Andras, Karl Breckon, Stephen Newberry, Ken Douglass, Steve Schilder - Peer reviewers with comments

WHAT WAS DONE?

Created a 45 page document, covering different drainage methods in use, to employ in residential and commercial construction to effect proper drainage, with consideration of the drainage on the environment and the foundation. Additional 160 pages of appended material.

Does not cover irrigation for the sake of foundation performance.

WHEN WAS IT DONE?

- Sanctioned 25 March 2009
- First meeting 7 October 2009
- Met monthly for two years until submitted for peer review
- Met bi-monthly after peer review
- Involved 37 revisions
- Published 5 March 2012

WHY WAS IT DONE?

- There was a lack of trustworthy information available in the literature and the internet which was comprehensive in scope and depth.
- Especially, lack of reliable information on French drains.

SECTIONS

- TITLE
- PREFACE
- GLOSSARY
- TABLE OF CONTENTS
- INTRODUCTION
- DRAINAGE
  - SOURCES
  - COLLECTION AND MANAGEMENT
  - DISPOSAL
- DRAINAGE EFFECTS ON FOUNDATIONS
  - COMMON DRAINAGE PROBLEMS
  - SITE SOIL TYPES
- REFERENCES

Generally, drainage system write-ups were separated into sections:

- **General description**
- **Purpose and application**
- **Planning**
- **Construction considerations**
- **Maintenance**

Drainage effects write-up was separated into three soil types:

- **Clay**
- **Silt**
- **Sand**

PREFACE - LIMITATIONS

- **INTENDED AUDIENCE** - ***persons seeking an understanding of the function of drainage and the proper construction to effect proper drainage in the vicinity of new and existing residential and low-rise building construction***

- **SPECIFIC AUDIENCE** - ***builders and contractors, owners, surveyors, foundation design engineers, geotechnical engineers, landscapers, landscape architects, civil engineers, and others***

- **GEOGRAPHICAL** - ***does not foresee geographical limitations on the use of this document***

GLOSSARY

Found to be necessary due to unclear usage of terms.

From the Introduction*: Describing drainage involves using terms which may have two or more commonly used meanings, such as the word "grade": 1) inclination with the horizon, and 2) the level at which the ground intersects the foundation of a building, and 3) the surface of the ground. Also consider the word "drain": 1) verb, to draw off liquid, 2) noun, means (such as piping) by which liquid matter is drained, and 3) noun, a plumbing fixture that provides an exit point for waste water. Also, there are many local variations on terms used and there is little standardization of terms in the description of manufactured products.*

GLOSSARY – Continued

An effort has been exerted in this paper to reduce the ambiguities in the use of drainage language, including a glossary, but the reader should be aware of the imprecision in the language and consider the context.

There was much discussion about inclusion of terms, definition of terms, usage of terms, from the beginning to the end of the committee. 30 terms were defined.

GLOSSARY - EXCERPT

- **Discharge – Exiting of water flow from a drainage device or conduit.**
- **Disposal, dispose, disposal point – The discharge of water flow to a specific site. Disposal may be to a drainage infrastructure, a dry well, remote property, or other surface features or drainage devices.**
- **Drainage Infrastructure – System components for handling water runoffs from residential and commercial properties, administered by a city, county, or area drainage authority. The system may include rivers, canals, ditches, storm sewer systems, and detention/retention ponds.**
- **Drop – Elevation difference from collection point to discharge point.**

INTRODUCTION

SCOPE - ***The purpose of this paper is to provide information on drainage systems and methods that may be employed to control water, which may have an effect on the performance of the foundation.***

GENERAL CONSIDERATIONS -

- **Elevate foundation to allow for proper drainage**
- ***Improper drainage can lead to erosion, poor lawn health, flooding/ponding, infestation of mosquitoes and algae, wood rot, and other undesirable consequences.***
- ***Proper drainage will not adversely affect the foundation, yard, surrounding properties, or the infrastructure transport and disposal system,*** **and** ***may also serve to replenish the soil with moisture and to recharge aquifers.***

GENERAL CONSIDERATIONS – Continued

- **Normally more than one way to design a drainage system, basic choice is to transport water to discharge point over the surface or in underground piping.**
- **Advantages of surface systems include:**
  - **Examine system operation visually**
  - **Reduced capital expenditure**
  - **Resistance to clogging and silting**
  - **Return water back to soil**
  - **Reduce load on drainage infrastructure**

GENERAL CONSIDERATIONS – Continued

- **Advantages of underground piping systems include:**
  - **Ability to route around obstructions**
  - **If regrading undesirable**
  - **Will not erode soils**
  - **Avoid surface standing water in swales and ditches**
- **Normally more than one way to construct a drainage system. More complex systems should be left to professionals.**
- **Rain barrels and collection bladders beyond scope of this paper**
- **Requirements of local jurisdictions should be addressed.**
- ***Systems that contain standing water and open to the atmosphere can function as mosquito breeding areas, and create a possible safety hazard, and should be avoided.***

DRAINAGE

SOURCES OF WATER

- **Rainfall**

DRAINAGE - SOURCES OF WATER - Continued

- **Irrigation systems**

DRAINAGE - SOURCES OF WATER - Continued

- **Underground**

DRAINAGE - SOURCES OF WATER - Continued

- **Neighboring properties**

DRAINAGE - SOURCES OF WATER - Continued

- **Condensate**

DRAINAGE – COLLECTION AND MANAGEMENT
Roof gutters, pitched roofs - General

3 Types

- **Low capacity common sizes attached to eaves**
- **High capacity semi-custom sizes attached to eaves**
- **Integral gutters draining within roof and walls**

Required by IRC in areas where expansive or collapsible soil are known to exist next to foundation walls (e.g. basements, stem walls).

IRC also states that the gutter system must collect and discharge all roof drainage to the ground surface at least 5 feet from foundation walls or to an approved drainage system, committee opinion is may not be sufficient if basement walls have backfills that exceed 5 feet in width at the surface.

DRAINAGE – COLLECTION AND MANAGEMENT
Roof gutters, pitched roofs – General - Continued

Expansive soil with effective plasticity index (PI) of 35 or greater (usually soil with high clay content) have a large shrink/swell potential with changes in moisture content of the soil. This soil condition can affect both slabs-on-ground and foundation walls.

Therefore, in these cases, full guttering with underground drainage (non-perforated piping) is recommended with appropriate water management to carry the water away from areas that can affect the foundation support soil.

DRAINAGE – COLLECTION AND MANAGEMENT
Roof gutters, pitched roofs – Purpose & Application, Planning, Construction, Maintenance

More information on this topic in paper.

DRAINAGE – COLLECTION AND MANAGEMENT

Roof drainage, low sloped roofs - General

With a pitched roof, the water management normally begins at the edges of the roof, due to the natural flow of water from the inclined roof surface. With a low-sloped roof, water management must be considered throughout the surface of the roof. Low-sloped roofs must be installed with features to manage the rainfall loads. Typical features for a low-sloped roof are a slight slope for drainage, normally no less than ¼" in 12 inches, roof drains, and scuppers/overflow scuppers through parapet walls.

DRAINAGE – COLLECTION AND MANAGEMENT
Roof drainage, low sloped roofs – Purpose & Application

Balcony decking must be constructed with same techniques as flat or low-sloped roof, but resistant to foot traffic.

No Planning, Construction Considerations, and Maintenance sections in paper.

DRAINAGE – COLLECTION AND MANAGEMENT
French Drains - General

The term "French drain" is often misused. A French drain does not refer to a single-point surface drain. Some will call a gravel filled trench drain a French drain (see section 2.2.6), but a French drain is a system for collection of subsurface free water, transport, and disposal, and is not used to drain surface water.

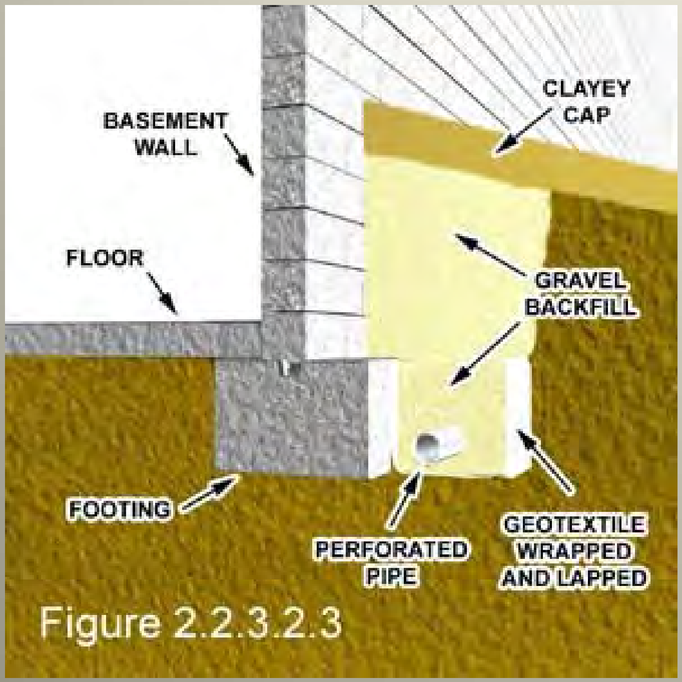
DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Purpose and Application

- ***The application for French drains is typically for the desiccation of chronically wet soil, and for diversion of groundwater away from a subterranean structure, such as a basement.***
- **Discussion of the effect of swelling soils on retaining walls, slab-on-ground foundations, and basements.**
- **Low production rates will tend to silt the piping, so consideration for maintenance is high. Movement of soils will affect installed slope.**
- **The source of the water should be investigated and resolved if possible, preferable to installing the french drain system.**

DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Planning

- First, check for the presence of free water under the soil surface, presence of free water at surface depressions, use plumbers probe, dig posthole and monitor for water.
- Plan layout, avoid near foundation, select disposal method, can use dry well.
- Discussion of depth of collection section.
- Areas with tree roots and not requiring drainage should have non-perforated pipe.

DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Planning - Continued



- **Areas of a basement below grade should have a perimeter drainage system installed, similar to a French drain system, as shown at left.**
- **These perimeter drains become clogged and ineffective over time, and require repair. If repair is ineffective, replacement should be considered, and is usually accomplished by installing a collector from inside the basement.**

DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Planning - Continued

- Do not charge the French drainage system with surface drainage.
- Two types of collection piping, PVC and flexible corrugated PE. Discussion of physical attributes and advantages and disadvantages of each.
- Install cleanouts.
- Install geotextiles with root inhibitors if applicable.

DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Construction Considerations

- Basement drainage not covered.
- Trench 12" wide minimum, taper transition out of perforated pipe to resist collecting water. Main course of water is through media, enters pipe when rates are higher or flow blocked.
- Geotextile normally placed in trench, best practice, but sometimes applied directly to pipe.
- Comprehensive description of construction of a French drain.
- Perforated pipe holes in 4 and 8 o'clock positions.

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DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Construction Considerations - Continued

Figure 2.2.3.3.2

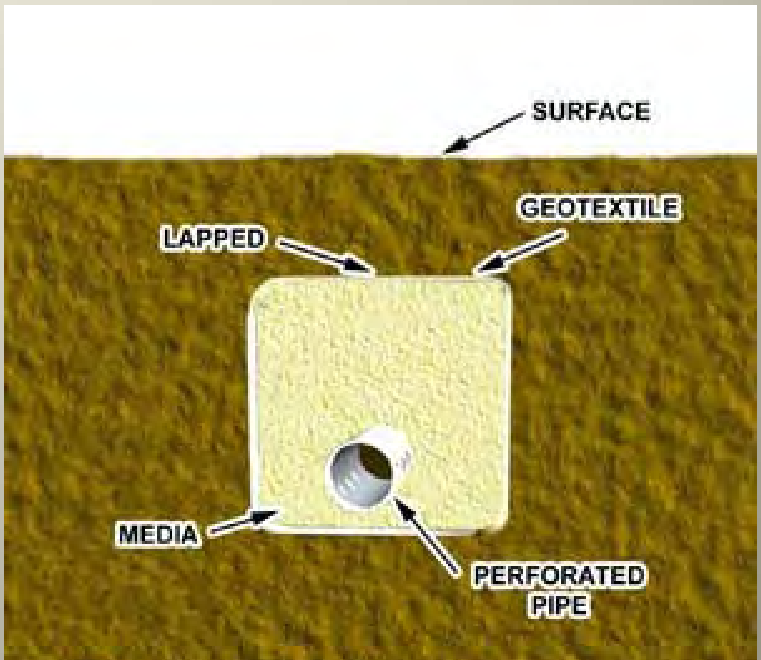

Figure 2.2.3.3.1

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DRAINAGE – COLLECTION AND MANAGEMENT
French Drains – Maintenance

- Will become clogged or silted over time.
- Access through cleanouts will allow maintenance without digging out.
- First effort with water hose and jet nozzle.
- Second effort with rotating rooter (cannot use with corrugated pipe).
- Third effort, investigate cause with sewer camera.

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – General

- Set into soil or hard surface, only cover soil applications.
- Also referred to as surface drain, point drain, or yard drain.
- Consists of collectors at the surface and non-perforated piping underground.

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Purpose and Application

- Important that collection points be at areas that will pond or collect, or grade soils to direct water to drains (basin effect).
- Normally several collectors feed into a single outlet.

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning

- Conduct topographical survey to establish existing grade.
- Low areas will be suitable locations for collectors.
- Remember that basin effect and collector box will consume several inches of head.
- If available drop from inlet grade to discharge is less than required drop, consider a surface drainage system.
- If area drain remains best option despite not enough available drop, consider sump well and sump pump.
- Do not drain to dry well, not enough capacity.
- Cutout of curb for discharge to street causes problems if not correct; should be Schedule 40, double 3” pipes better than single 4”, cut flush to curb.

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

- **Pop-up discharge is alternative to curb cutout.**
- **Collector consists of grate, optional riser, optional debris basket, base. Riser connects to an inlet pipe, base connects to an outlet pipe.**
- **Each collector handles the watershed from about 300 sqft.**
- **Four inch pipe handles drainage from 4 to 8 collectors.**
- **Piping can be configured in serial or parallel fashion, parallel allows better use of available drop, serial utilizes less materials.**
- **Where drainage legs connect, downstream pipe may have to be larger.**

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

- **Dry fit joints will incur some minor leakage, but can be easier to repair or modify system.**
- **When drainage slope is below recommended amount, possibility of a belly or reverse flow is magnified if soil has high shrink/swell potential.**
- ***Depending on the size, material, and availability, the pipe segments can have either dry fit connections, gasketed push-on connections, or cemented connections*.**
- **Discussion and examples of simple drainage runs showing effects of bellies, head, and fitting loss on flowrates.**

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

Manning flow equation introduced in this section.

The relationship of flow to other drainage system variable can be calculated. The classic Manning equation is:

$$Q = A * 1.49/n * R^{0.667} * S^{0.5}$$

where:
Q – flow rate; cubic feet per sec (cfs)
A – cross sectional area of flow; square feet (sqft)
n – the fluid drag coefficient; dimensionless; per the tables below
R – hydraulic radius; defined below
S – slope of pipe; feet of height / feet of length (ft/ft)

$$R = A \div P$$

where:
R – hydraulic radius
A – cross sectional area of flow; square feet (sqft)
P – wetted perimeter; feet

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

Simplified equations based on Manning introduced, with choice of several arguments and units more consistent with residential use. The first set of equations is for plastic pipe.

$$h = .016 * l * Q^{2} \div ID^{5.33}$$
$$ID = .46 * (l/h)^{.188} \; x \; Q^{.376}$$
$$Q = 7.9 * (h/l)^{.5} * ID^{2.66}$$

where:
h – head; inches
l – pipe length; feet
Q – flow rate; gallons per minute (gpm)
ID – inside diameter of pipe; inches

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

The second set of equations is for pipe other than plastic.

If piping materials other than plastic are used, the above equations become:

$$h = 162 * l * [Q * n]^2 \div ID^{5.33}$$
$$ID = 2.63 * [Q * n]^{.38} \div [h/l]^{.188}$$
$$Q = [.0785 \div n] * (h/l)^{.5} * ID^{2.66}$$

where:
n – fluid drag coefficient; dimensionless, per the table below:

MATERIAL	FLUID DRAG COEFFICIENT, n
Plastic	.010
Steel	.011
Concrete	.012
Corrugated Steel	.022

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Planning - Continued

The third set of equations is for non-round channels in partial flow with sides consisting of various soil/plant materials.

The Manning equation in a more complex form can also be used for open channels with various channel linings.

$$h = 15.6 * [Q*n]^2 * l * p_w^{1.34} \div A^{3.34}$$
$$A = 2.28 * [Q*n]^{.6} * [l/h]^{.3} * p_w^{.4}$$
$$Q = [.253 \div n] * [h/l]^{.5} * A^{1.67} \div p_w^{.67}$$

where:
n – fluid drag coefficient; dimensionless, per the table below
A – cross section area of fluid; square inches
p_w – wetted perimeter; inches

SURFACE MATERIALS	n
Earth, uniform section, clean, recently completed	.016-.018
Earth, uniform section, after weathering	.018-.020
Earth, uniform section, short grass, few weeds	.022-.027
Earth, uniform section, graveled soil, clean	.022-.025
Earth, fairly uniform section, no vegetation	.022-.025

DRAINAGE – COLLECTION AND MANAGEMENT
Area Drains – Construction Considerations, Maintenance

More information on this topic in paper

DRAINAGE – COLLECTION AND MANAGEMENT
Berms and Swales

- A berm is a raised area used to slow runoff on steep slopes.
- A swale is a ditch with a gentle side slope, used to direct water towards a storm drain or street.
- Vegetated swale slows and absorbs water in transit.

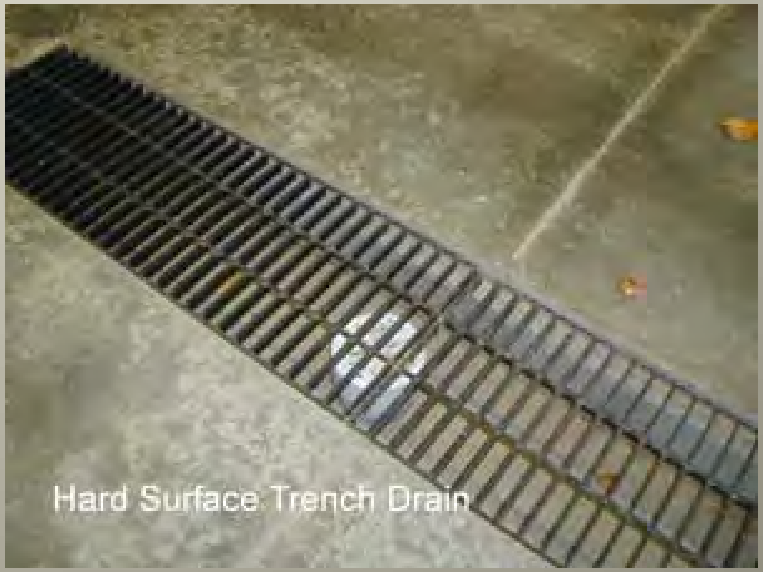
DRAINAGE – COLLECTION AND MANAGEMENT
Diversion Wall

- **A short wall installed between the upslope source of runoff and the property to be protected, to divert the runoff.**

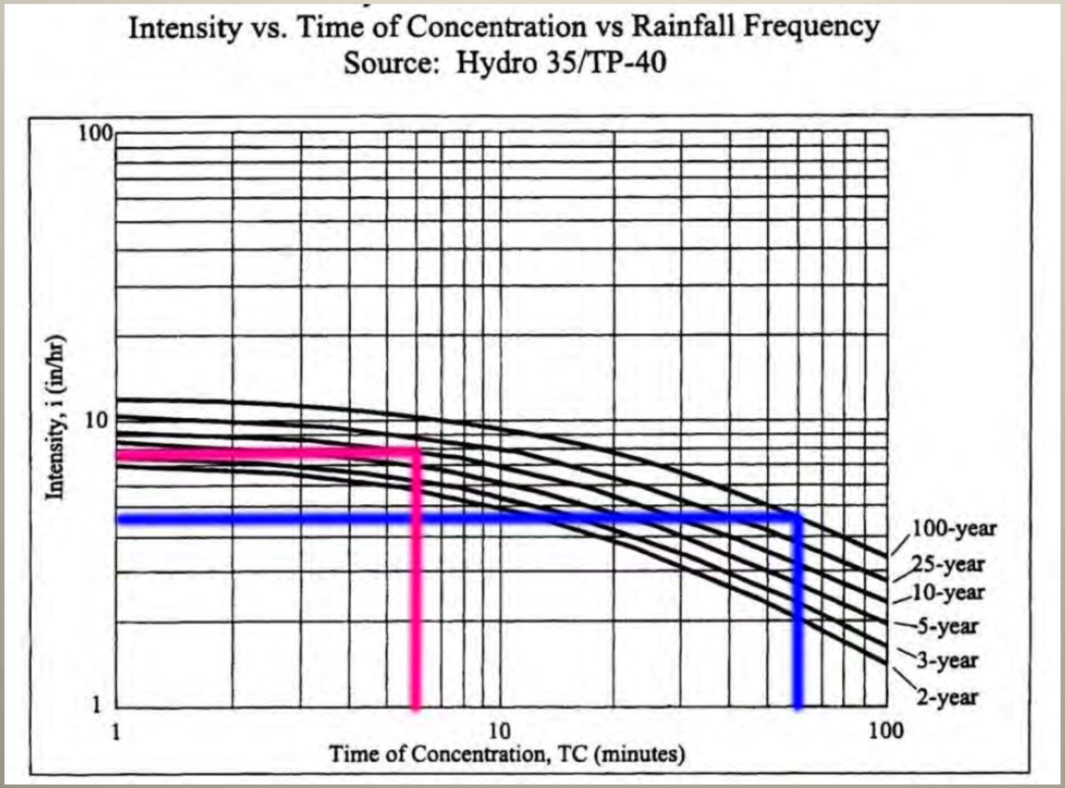
DRAINAGE – COLLECTION AND MANAGEMENT
Trench Drain - General

- A system to collect surface water, many times longer than wide, generally laid across sloping landscape or hard surfaces.
- Collection is at grade.
- Other names are strip drains, slot drains, or grate drains.
- Take two forms:
  - Perforated pipe and media constructed like a French drain open at the surface, used in soil surface applications, called a field trench drain.
  - Grate and open channel constructed like a street gutter, used in hard surface applications, called a hard surface trench drain.

DRAINAGE – COLLECTION AND MANAGEMENT
Trench Drain – General - Continued



DRAINAGE – COLLECTION AND MANAGEMENT
Trench Drain – Purpose and Application, Planning, Construction Considerations/Maintenance



Rainfall intensity vs. time introduced in this section

More information on this topic in paper.

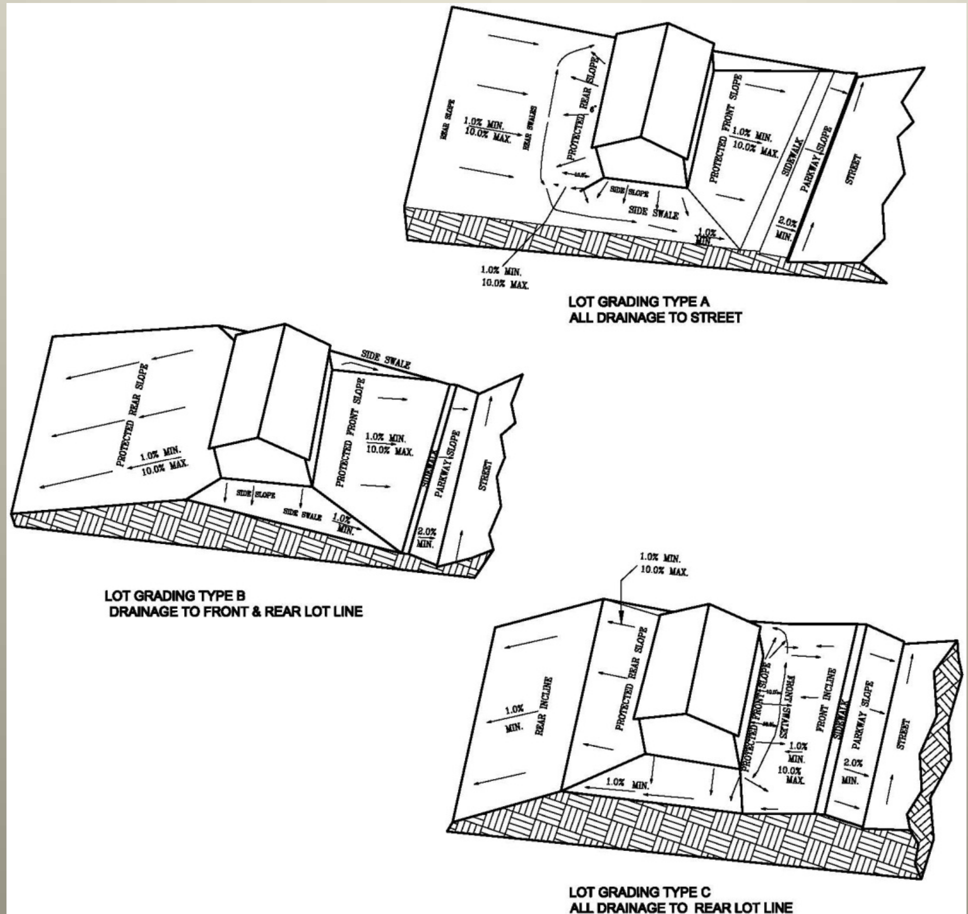
DRAINAGE – COLLECTION AND MANAGEMENT
Ground Surface – General

- Absorption by soils and vegetation important
- Grasses and vegetation slows water velocity
- Excessive slope may result in erosion
- Concrete and asphalt impervious, pavers and spaced bricks semi-pervious
- Bare soils are problematic, important to sod
- Where water stands, healthy lawn, generous thatch helpful
- Soils with organics more pervious
- River rock usage my inhibit drainage, inhibit observation of actual drainage patterns, and result in ponding
- Mulch surface is not the drainage plane
- Avoid impounding water with bedding borders.

DRAINAGE – COLLECTION AND MANAGEMENT
Ground Surface – Lot Grading Types

- ***Therefore in the early planning stages of new construction, it is important to establish the lot grading philosophy in order to help achieve proper drainage and foundation performance while not impacting neighboring adjacent lots.***
- **FHA has three main classes of lot drainage types:**
  - **Type A – Rear-to-Front**
  - **Type B – Rear-to-Rear and Front-to-Front**
  - **Type C – Front-to-Rear**

DRAINAGE – COLLECTION AND MANAGEMENT
Ground Surface – Lot Grading Types



DRAINAGE – COLLECTION AND MANAGEMENT
Ground Surface – Purpose & Application, Planning, Construction Considerations

More information on this topic in paper

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DRAINAGE – COLLECTION AND MANAGEMENT

- Point-to-Point Drainage
- Soil Terracing
- Retaining Walls
- Water Barrier
- Flood Mitigation
- Sump Pumps

More information on these topics in paper

DRAINAGE – DISPOSAL
Curb-and-Gutter Street Drainage

- Normal drainage in urban or suburban sites is to the street
- Street is curbed and crowned to carry water to storm inlets
- Streets designed to flood at higher rainfall rates
- Private streets and alleys may drain to centerline
- Foundations required by IBC and IRC to be 12" + 2% above distance to street curb

DRAINAGE – DISPOSAL
Roadside Ditch

- Drainage is natural with addition of drainage along and across roadways
- Roads normally above level of surroundings
- Culverts under roadways and driveways

DRAINAGE – DISPOSAL
Dry Well

- When disposal options are limited, and amount of water to be disposed of is limited, a viable option
- Consist of a surface drain above a collection well
- Water is received during rainfall, and disposed of slowly into surrounding soil

DRAINAGE – DISPOSAL
Subsurface Sinks

- When pervious surface overlies impervious layer, viable option
- Consists of hole dug through impervious layer, filled with porous medium
- Water is received during rainfall, and disposed of slowly into soils underneath the impervious layer

DRAINAGE – DISPOSAL
Evaporation and Plant Uptake

- **When grades are flat, drainage options limited, evaporation is viable option**
- **Grade to expose largest area of water to evaporate**
- **Lawns and trees can absorb water**

DRAINAGE – DISPOSAL
Soil Absorption

- Can be enhanced by working non-clay constituents into soil, terracing, plantings, and aeration of soil
- When drainage pipes away from foundation, can use perforated pipe
- Perforated pipe as disposal for French drain
- Portion of drainage path can be above ground
- Perc test to determine soil absorption

DRAINAGE – DISPOSAL
Impact on Neighboring Property

- Impact not allowed by jurisdictions
- Some do not allow net increase in fill
- Some allow net increase, but drainage must to directed to infrastructure, not neighboring properties
- Some limit amount of impervious surface, or require mitigation of increase
- Piping surface water into sanitary drainage illegal in most cities, and causes sewer backups

EFFECTS ON FOUNDATION

COMMON DRAINAGE PROBLEMS
From FPA-SC-06-0, Homebuyers Guide for Foundation Evaluation, checklist items to avoid problems

- Drainage away from foundation
- Location of all drains and downspouts
- Crawlspace ventilation, crawlspace moisture conditions
- Recently removed trees near foundation
- Planters near house, drainage under mulch
- Sprinkler heads
- Rock fill
- Flatwork abutting foundation drains away

EFFECTS ON FOUNDATION – SITE SOIL TYPES

It is important to be aware of the soil composition in the upper strata in order to evaluate the risks associated with inadequate drainage.

EFFECTS ON FOUNDATION – SITE SOIL TYPES
Clay

- May have cracks and voids near surface leading to lower active strata, thus concern for ponding
- Normally considered impermeable
- Can draw water from all directions
- Unsaturated clay presents design challenges
- Active clay changes volume when moisture changes, thus concern for foundations
- Good drainage should be maintained during construction through the life of the foundation.

EFFECTS ON FOUNDATION – SITE SOIL TYPES
Silt

- Non-cohesive, highly permeable, non-active
- Can draw water from higher elevations
- Weak when too dry or too wet
- Concern for active clay sub-strata

EFFECTS ON FOUNDATION – SITE SOIL TYPES
Sand

- Non-cohesive, highly permeable, non-active
- Shape and material allows more bearing than silts
- Erosion a concern
- Can draw roots if wet
- Concern for active clay sub-strata
- Sand and silt should never be used for rough grading over active clays.

REFERENCE MATERIALS

- References cited and non-cited in paper are listed
- HUD Handbook 4140.3
- HUD Data Sheet 72
- HUD Data Sheet 79g

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Download
Document No. FPA-SC-17-0 “Drainage Guidelines”
at: http://www.foundationperformance.org/committee_papers.cfm