PDHonline Course C587 (2 PDH)

Groundwater Control for Design & Construction

Instructor: T. E. McLaughlin, PE

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

Groundwater Control for Design & Construction

T. E. McLaughlin, P.E.

1. Introduction

This course is to be taken in conjunction with the open-source DoD Handbook **UFC 3-220-05**, Dewatering and Groundwater Control. This publication should be downloaded and easily available to you while taking the course. You can do this by one of the following methods: a) download the Handbook and make it available on your hard drive; b) download and copy the Handbook to a CD which you will then use during the course; c) download and print the Handbook on paper and refer to it with this method. Test questions are taken either from this course text, or by reference to the Handbook Chapters 1, 2, and 3, specifically the text and figures/tables. You will need to have the Course text and Handbook available either via your computer screen or in printed form on paper when taking the test.

2. General Information on Groundwater Control

In the following paragraphs and sections we will review DoD Publication **UFC 3-220-05** [the Handbook] in detail because control of groundwater is a fundamental issue for highway designers and anyone involved with horizontal construction. This publication contains important detailed information applicable to highway designs and/or horizontal construction in any location.

Go to the Handbook second chapter and check the list of groundwater control methods shown in Table 2-1, p.2-11, "Summary of Groundwater Control Methods." Also review Figure 2-13, p. 2-14, "Recharge of groundwater to prevent settlement....."

Then check the Handbook page 5-4 for an illustration of a dewatering pump.

©2012 T.E. McLaughlin, P.E.

The following list indicates primary groundwater control methods from **UFC 3-220-05**, Table 2-1, p. 2-11:

1. Sumps and diches;
2. Conventional wellpoint system;
3. Vacuum wellpoint system;
4. Jet-eductor wellpoint;
5. Deep-well systems;
6. Vertical sand drains;
7. Electro-osmosis;
8. Cutoffs.

What can we do with this information as designers? We will discuss the hazards of leaving "completion of the design" to the contractor or to his subcontractors in the following sections. One particular recurring issue is the problem of unforseen or hidden conditions on a construction site, which could have been or should have been anticipated by the design firm or "engineer of record." These hidden conditions usually involve geotechnical issues for horizontal and highway construction. If you are the project designer or "engineer of record," it falls back to you to note, accurately describe, and deal with potential hidden conditions as comprehensively as possible prior to the project being placed out "on the street" for actual bidding. If you are designing a project with known groundwater problems, i.e. high groundwater table, difficult soils (clays), and/or limited work area due to either right-of-way issues or elevation changes, it would seem reasonable to address these issues within the bid documents either by:

a)- geotechnical report,
b)- inclusion of groundwater control pay items,
c)- detailed special provisions and specifications, or
d)- all of the above items,

in order to give the bidders advance warning of anticipated groundwater problems during construction. See Handbook Chapter 7 for detailed information on specs.

The information here is applicable to civilian as well as military projects.

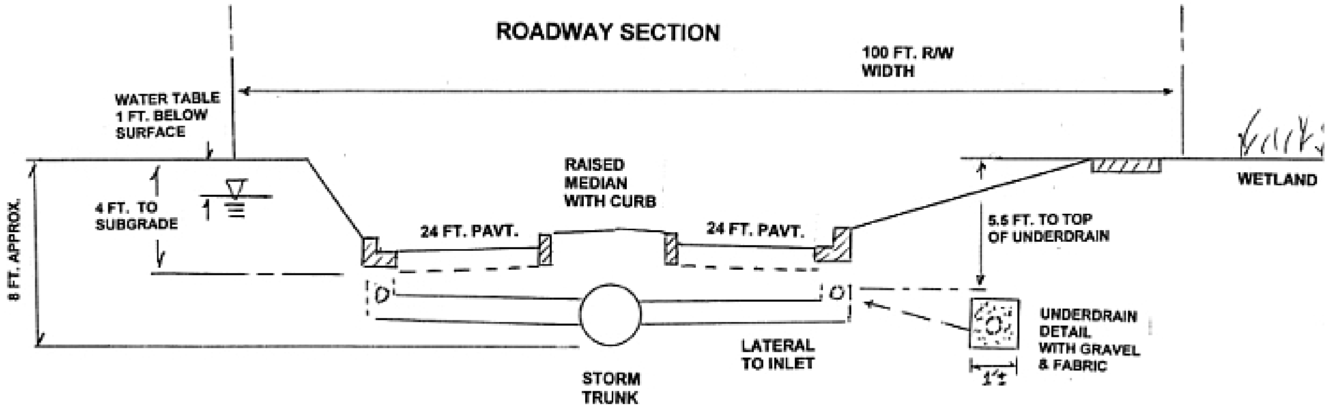
This comprehensive DoD Handbook, **UFC 3-220-05**, has a detailed Chapter 4 on design of groundwater control systems, with charts, equations, and graphical analyses of various control methods. The complexity of groundwater control does not usually lend itself to placing the problem or problems into a "contractor issue" category, and if resolution is left to the low bidder on a construction project, groundwater problems will likely end up as either a change order or a lawsuit. If you and your firm have a project with noteworthy groundwater issues and you do not have the expertise to deal with and resolve anticipated construction site conditions and groundwater problems during the design phase, it is best to retain a geotechnical engineer or firm with specific experience in dealing with these types of situations. The bottom line is that *significant groundwater issues should be resolved as much as possible during design*, not during construction.

For tips and specific information on projects with groundwater issues, **UFC 3-220-05** Chapter 7 describes specifications and contract terms which you may wish to include in your project in order to clarify the contractor's responsibilities related to groundwater on a specific project. This information will not appear on the test for this course, but it can be valuable to the engineer of record during bid package preparation.

3. EXAMPLE ONE

Highway construction project with groundwater one ft. below the surface:

If the soil is sandy or well-drained, ditches and/or sumps can be used to install shallow features such as road base, curb, etc. But what is to be done to provide a permanently firm, dry subgrade for the pavement? For installation of storm drain piping at depths up to around 12 ft. below the surface, a conventional wellpoint system may be the best answer, depending on soil classification. The problem of permanent water table lowering to maintain pavement integrity may be more difficult. Review the cross-section drawing on the next page:



What are the problems with this design?

a) Underdrain as a maintenance issue?
b) Wetland hydration?
c) Keeping the subgrade dry?
d) Cut section in high water table area?
e) Side effects of permenently lowering the water table?
f) Construction dewatering?

Let's examine each issue in detail -

a) Underdrain: With approximately 5 ft. of hydraulic head on the underdrain, siltation of the fabric will be a problem. If the soil is a sand with particle size ranging between 0.2 and 2 mm [see **UFC 3-220-05**, Figure 2-12, p. 2-13] with moderate to good permeability, a gravity underdrain would work if it is installed properly. Underdrains are always maintenance headaches, and once they silt up, they must be replaced. It would be good design practice to consult a geotechnical engineer for assistance with this situation. The maintaining agency may also have advice concerning its experience with underdrains and similar soils.

b) Wetland hydration: A wetland adjacent to a roadway cut section is a real problem. Permitting agencies will require extraordinary measures to keep the wetland hydrated, and this leads to sheet pile barriers or other types of hydraulic barriers or cutoff walls below the surface to prevent the wetland from draining toward the roadway. In some areas, permitting agencies will allow a wetland to be "relocated," with reconstruction at 3 to 5 times the size of the original wetland to insure plant regeneration. Discussion with all involved permitting agencies should be initiated prior to commencing the design. Alternatives to the cut section should also be reviewed.

c) Subgrade saturation: No roadway can survive a saturated subgrade. Heavy, repeated wheel loads will pound the pavement to pieces in a short time period. This is one of the most fundamental issues in highway design. For the example above, we can define subgrade as the 12 inches of soil immediately below the subbase course (see link below). Some agencies refer to this layer as "stabilized subgrade," or "compacted subgrade." For a high groundwater condition, a subbase configured as a drainage blanket may be necessary. There are many possibilities for use as a subbase, as follows: [for examples only]

[1] - 12 inches of graded, crushed gravel on top of a well-drained sand layer.
[2] - 24 inches (varies) of coarse sand.
[3] - 12 to 24 inches of coarse gravel, etc.

It is assumed these subbase layers would lie immediately adjacent to, and connect with, a continuous longitudinal underdrain system [blanket drain - see link below]. Assuming the pavement structural and base courses are at least one ft. in thickness, the subbase/subgrade illustrations indicated should place the wheel loads approximately 3 to 4 ft. above any saturated soils. This depth should be checked carefully depending on anticipated wheel loads and soil characteristics. The 3 ft. dimension indicated may be inadequate for some designs.

For information on subbase drainage, go to the web site below and download the geotextile handbook:

http://www.typargeotextiles.com/PDFs/TG-SubsurfaceDrains.pdf

This geotextile handbook and information is for your reference only, and is not used for test questions.

See also **UFC 3-220-05**, Figure 2-9, page 2-9.

d) Use of cut section in high water table areas: The cut section design in a high water table area should be reviewed for possible reconfiguration as a fill section, if at all possible. Numerous problems with subgrade drainage warrant a brief feasibility review and/or study to consider the alternatives.

e) Side effects of permanently lowering the water table: A geotechnical review is in order. Will nearby structures settle, with resulting structural cracking or worse? What is the effect on plant growth? Side effect on adjacent property? Will unpredictable settlement occur? What is the lateral extent of the dewatering/water table reduction? A technical analysis and review are necessary for liability purposes.

f) Construction dewatering: Of the eight methods commonly used to control groundwater during construction [**UFC 3-220-05** Table 2-1, p. 2-11] which we noted previously, which one appears to be the best for this example?

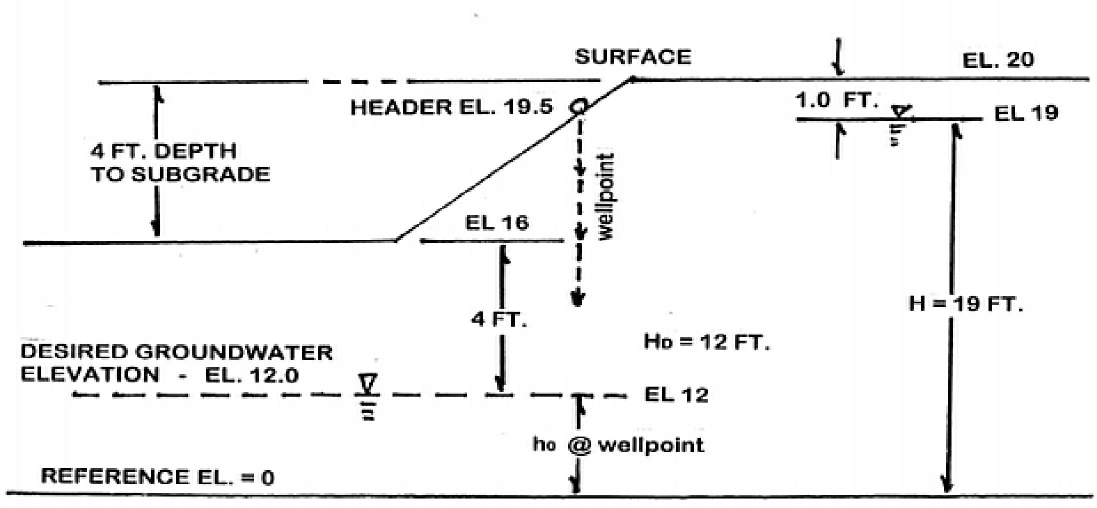
Depending on soil permeability, either the conventional wellpoint system or the vacuum wellpoint system would be feasible on this project. We will continue the construction dewatering analysis in **EXAMPLE TWO**, below.

4. EXAMPLE TWO

Construction dewatering:

Turn to **UFC 3-220-05**, APPENDIX D - Figure D-1, p. D-2, and review it for similarities to the cut section in **EXAMPLE ONE,** above. In our **EXAMPLE ONE,** we do not have the work area or right-of-way required to install two parallel, staged wellpoint systems on each side of the roadway.

Using the same basic parameters as in **UFC 3-220-05** Figure D-1, p. D-2, review the section diagram on the next page:



EXAMPLE TWO - SECTION (assume one wellpoint line & header along each side of roadway)

Assuming the soil permeability is = 0.2 ft./min. as in Figure D-1, (noted previously), calculate **ho** for the section above for a single stage of wellpoints along one side of the excavation:

hD = ho [1.48 / 700] x (19 - ho) + 1.0] >>
12 FT. = ho [0.002114 x (19 - ho) + 1.0]

working the equation, we obtain:
ho = 12 FT. / [0.002114 x (19 - ho) + 1.0] = 11.82 ft.

What is Qp ? From **UFC 3-220-05** Figure 4-3, p. 4-4, (gravity flow) we use the same equation as found in **UFC 3-220-05** Figure D-1**:**

Qp = [0.73 + 0.27 x [(H - ho) / H] x (k / 2L) x [H^2 - ho^2]
(assume L = 700 ft.] (see note 1 below)

Qp = [0.73 + 0.27 x [(19 - 11.82) / 19] x (0.2 / { 2 x 700 }) x [361 - 139.71]

Qp = 0.0263 CFM / FT. = 0.2 GPM per FT. of header.

Using a 10 FT. wellpoint spacing, the configuration will produce approximately 2 GPM.

(Also review **UFC 3-220-05** Figure 4-1 and Figure 4-2, pp. 4-2 & 4-3)

note 1 - This 700 FT. dimension can be calculated from UFC 3-220-05 Chapter 4, p. 4-2 & Fig. 4-2.

note 2 - Because this course is concerned with groundwater control, we will refrain from deriving the parameters used in the examples in order to avoid becoming lost in the minutiae of the hydraulic equations.

With proper choice of pump and wellpoints, a contractor should be able to dewater this roadway section and install the storm line and subgrade satisfactorily. Look carefully at **UFC 3-220-05** Figure 4-30, p. 4-35 to determine wellpoint filter sand size in relation to aquifer soil gradation; this process is described in Section 4-6 on page 4-34. In addition to the wellpoints, some gravel bedding under the storm pipe may be required along with a sump pump to drain this pipeline excavation. Refer to Figure 2-12 on p. 2-13 for limits of gravity drainage vs. soil grain size. Figure 4-5 on p. 4-6 further illustrates our example and gives an analysis for artesian and gravity flow.

Review the gravity flow equation on Figure 4-5 for **hD** at the center of the pipe trench:

hD = ho[{ (C1C2) / L } x (H - ho) + 1]

What is the groundwater depth at the pipe trench? Using the EXAMPLE TWO SECTION above, and Figure 4-5 on p. 4-6, we can calculate this **hD** as shown on the following page:

For this equation, L = 700 FT. to stable water table elevation,
where H = 19 FT.

l = 48 FT. for use in **UFC 3-220-05** Figure 4-5, p. 4-6.
l / ho = 4.06 >>>> C1 = 1.0

b = 2.5 inches = 0.208 ft.

b / H = [0.208 / 19] = 0.011 >>>> C2 = 0.06

We are ready to solve the equation for **hD** -

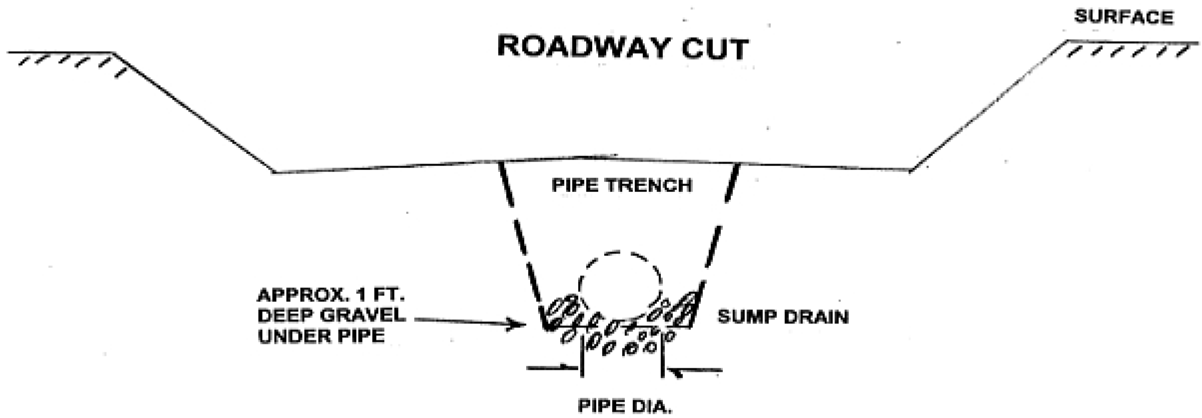
hD = 11.82 [{ (1.0 x 0.06) / 700} x (19 - 11.82) + 1]

hD = 11.82727 >>>> not much change

5. EXAMPLE THREE

Minor groundwater intrusion:

Referring again to the **EXAMPLE TWO SECTION** above, if the pipe trench is 5 ft. deep, the pipe will be installed in approx. one foot of water. Hence, some additional dewatering will be required, most likely a sump drain with pump. The "Roadway Cut" diagram shown on the following page details the storm line installation:



A sump pump of appropriate size can be used at the low point of the pipe installation, most likely with a shallow "well" which is cut two or three ft. below the pipe bottom and filled with gravel. Should ground water flow prove to be substantial, more than one such "well" may be required, along with additional pumps or pumping capacity.

Note that these "sump pumps" described above do not require wellpoints and suction lines as does a wellpoint installation. Sump pumps are generally much less expensive than a complete wellpoint system.

For information on the characteristics of the soil and geologic features of a specific project, refer to the Handbook Chapter 3, Geologic, Soil, and Groundwater Investigations. We note this Handbook chapter here in order to emphasize the importance of the geotechnical engineering to be performed prior to commencing design for a project, as it may enable the designer to make accommodations for high groundwater conditions during construction, and possibly avoid costly dewatering operations during the construction phase. This type of information will help the designer to determine if a sump pump arrangement may be satisfactory in lieu of a complex and costly wellpoint dewatering installation.

END OF COURSE TEXT
[ed. 07-22-2012]