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# Teaching Farmland Drainage Design Features to Contractors and Service Providers

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## **Teaching Farmland Drainage Design Features to Contractors and Service Providers**

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**ABSTRACT.** *Farmland drainage is an integral part of Iowa's landscape and plays a critical role in its bio-economy. Production capacities of Iowa soils can only be optimized with well-designed and properly operating subsurface drainage systems. Features needing attention when designing and installing a new system or retrofitting an old one include drainage intensity (spacing and depth), drainage capacity (size and grade), water quality and quantity management (controlled drainage, shallow drainage, etc.), and the economics of payback. Iowa State University Extension & Outreach initiated the Iowa Drainage School in 2007 to educate stakeholders on subsurface drainage concepts customized to the upper Midwestern states. Three hundred thirty-five participants, consisting of contractors, engineers, drainage planners, land owners, farmers, agency staff, and drainage district supervisors, have attended the school. All participants completing the end-of-school evaluation have ranked the school good (45%) or excellent (55%) and reported making drainage decisions on over 1,100 acres per participant. A summary of participants' preferred methods of surveying and developing topographic maps, methods of determining drainage sizing and spacing, and developing drainage maps is presented. This paper summarizes the nine-year outreach efforts of Iowa Drainage School in terms of what students learned in the school, how they have used the knowledge gained, and how they have applied what they learned in the drainage school.*

**Keywords.** *Bioreactors, controlled drainage, drainage, design, quality, quantity, school, shallow drainage, spacing, sizing, training, water, wetlands.*

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## Introduction

Removal of excess soil water with the use of farmland subsurface drains is a common practice in the Midwestern United States and several other areas in the world. This practice is an integral part of Iowa's landscape and plays a critical role in its bio-economy. Production capacities of Iowa soils can only be optimized with well-designed and properly operating subsurface drainage systems. Somewhat poorly to poorly drained Iowa soils had subsurface drains installed during the late 19<sup>th</sup> and early 20<sup>th</sup> century to improve their productivity. Greater than 35% of Iowa's row-crop farmland or over 5.1 million ha of farmland is considered to be artificially drained (USDA-NASS, 2014). Several of these drainage systems are now older than 100 years or more, and are in need of upgrading either with installation of a completely new system or upgrading of an older system.

Features needing attention when designing and installing a new system or retrofitting an old one include drainage intensity (spacing and depth), drainage capacity (size and grade), water quality and quantity management (controlled drainage, shallow drainage, bioreactors, wetlands, etc.), and the economics of payback. Drainage contractors, professional engineers and consultants, USDA-NRCS professionals, county administrators, landowners, Iowa Drainage District Association officials, and others interested in subsurface drainage need guidance and training for design and maintenance of drainage systems. Several standards and technical guides available for use include Iowa drainage guide (ISUEO, 2008), drainage water management (USDA-NRCS, 2001), and standard for design and construction of subsurface drains in humid areas (ASABE Standards, 2015). These guides and standards, while useful, do not train stakeholders in the art and science of designing and installing subsurface drains.

Majority of the pre-existing systems are clay-tile drains and need upgrading as the clay-tiles have exhausted their life and are collapsing. This upgrading or retrofitting of the existing systems, along with the need of additional farmlands needing subsurface drainage, has created a need to install subsurface drains with the state of art knowledge. Iowa Drainage School was initiated in 2007 with a focus to train stakeholders in subsurface drainage concepts, planning and laying out drainage systems including surveying, laying out the system, calculating tile line sizes and spacing using actual field data, making connections, and setting up drainage control structures, NRCS program requirements, and fixing common drainage system issues. This school provides an opportunity to the stakeholders to gain knowledge which would otherwise be available in a college course.

Educational efforts, such as the Iowa Drainage School, need to capture the changes that occur subsequent to the training provided. These changes can be shed light on how the stakeholders are changing their practices for drainage design and how these changes are benefiting the farmer or the land owner as well as the environment. A few researchers have attempted to summarize the practices of drainage stakeholders. Nolte et al. (1987) summarized that engineers are typically involved in complex watershed scale drainage design projects where as the technicians are engaged in drainage designs needing both subsurface drainage designs and surface drainage improvements. The authors also summarized that the contractors are likely involved in on-farm subsurface drainage designs. Authors also discussed the role of drainage guides in subsurface drainage systems designs. These drainage guides serve the purpose of a good general reference but cannot be used for drainage designs in singularity. Experience and judgement dictate several of the farmland drainage design decisions.

Skaggs (1987) summarized that the art and science of farmland subsurface drainage had improved over the past twenty-five years, however, the majority of on-farm drainage design decisions were made based on prevailing customs or local traditions. Objective methods for developing drainage designs, conceptualized by several years of research, were still not leading how designs were tailored to needs. Engineered designs were identified as the need of the time by the author which could lead to optimizing crop production as well as dividends for the farmer. No summary of any educational efforts to influence or change customs and traditions was presented by the author.

Atherton et al. (2004) surveyed contractors in Ohio for identifying their drainage installation practices. Ninety percent of the respondents of the survey was comprised of contractors whose main profession was subsurface drainage design and installation. These contractors reported having installed ninety percent of the all of the drainage tile installed in Ohio in 1997. Several of the contractors surveyed reported using the same drain depth and spacing for drainage installation irrespective of the soil type on the farm. As suggested by Skaggs (1987), Atherton et al. (2004) also summarized that the soil type consideration was not an objective method used by contractors for drainage design and installation. Authors suggested that the educational efforts targeted towards improving the design practices used by the drainage contractors were needed.

Lagacé et al. (2010) shared an experience regarding certification of drainage enterprises in Québec, Canada. The Québec government interrupted subsurface drainage subsidies in 1991 which lead to significant dissolution of a positive attitude towards the drainage enterprises. The Québec Agricultural Drainage Contractors Association (QADCA) embarked on a drainage contractor certification process in 2002 to improve the services offered and for the survival of its member enterprises. As a part of this process, QADCA produced a standard and subsequently a certification protocol which the drainage enterprises used to obtain certification. The authors summarized that approximately eighty percent of the total drainage tiles installed in Québec were being performed by certified enterprises. The authors summarized that the process improved the training of the personnel involved in drainage installation and the quality of installations.

It is clear from the available literature that the training of stakeholders involved in farmland drainage is essential for better design and installation of the drainage systems. No data exists in the literature regarding the changes made by stakeholders such as producers or drainage contractors in their professional practice subsequent to being trained in a drainage school. Furthermore, the Iowa Drainage School has incorporated subsurface drainage water quality improvement practices into teaching drainage designs due to increased interest in water quality over the last decade. No data exists on how the drainage stakeholders are incorporating such practices in their drainage designs and are implementing such practices on the farmland. Lack of such data has led to the development of an online survey of the past participants of the Iowa Drainage School with the following objectives:

1. Access subsurface drainage installation activities of the drainage school participants,
2. Access incorporation of various drainage water management practices such as controlled drainage and shallow drainage into the drainage design,
3. Access the effectiveness of the drainage school training in influencing the drainage design decisions made by the drainage school participants.

## **Methodology**

A survey instrument was developed which was emailed to the past participants of the Iowa Drainage School. This survey instrument was approved by the Internal Review Board (IRB) in the Office of Responsible Research (ORR) of Iowa State University. A list of email addresses was compiled from the attendance records of the Iowa Drainage School from 2007 to 2015. As there were no repeat attendees, a list of past participants was compiled. All email addresses were considered valid and no attempt was made to revalidate the email addresses, i.e. if the addresses were still active. It was known that any invalid addresses will bounce back to the sender. An attempt was made to obtain a valid email address for the bounced back email addresses by making phone calls using the phone numbers provided by the participants at the time of registration. No further attempt was made to obtain an email addresses if the phone number was no longer in service.

A modified Dillman (1978) approach, similar to the one used by Atherton et al. (2004), was used in conducting this survey. An introductory email announcing the upcoming Iowa Drainage School Follow-up Survey was sent to all email addresses on the compiled past participant email list. The online survey web address was emailed to the same email address list three days after the announcement email requesting the participants to complete the survey using any device including a PC, a tablet, and/or a smartphone. This email also summarized the purpose of the survey and provided an option to the past participants to opt-out of the survey if they were not interested. One-week, three-weeks, and six-weeks following the emailing of the survey web address, a reminder email was sent to all past participants with the exception of the inactive email addresses.

## **Results and Discussion**

This survey was initiated on June 15, 2016 and an email introducing the survey was sent to 335 past participants of the Iowa Drainage School from 2007 to 2015. With the emails bouncing back for the non-functional email addresses, it was determined that only 207 email addresses were valid. Eighty-three participants from the group of 207 participated in the survey, with sixty-two submitting their responses and twenty-one responding to the questions but not submitting the survey. Nine participants out of the group of twenty-one, had only viewed the introduction to the survey and did not view remainder of the survey. Two respondents viewed all the questions on the survey but did not respond to any of them. The response rate for this survey was 40.1% (83/207) based on the respondents accessing the survey, whereas the usable responses were provided by 34.8% (72/207) of the respondents.

Results show that the respondents completing the survey consisted of producers (31%), service providers i.e. consultants (12%), contractors (54%), and others (4%). Close to 80% of these respondents had attended the school within the last four years. Based on the training received in the school, 41% of the respondents indicated that they had increased their service area, while 23% did not increase the service area, and 36% indicated that this question did not apply to them. These responses are in line with the classifications of who completed the survey. Typically, producers are not likely to increase the number of acres unless they purchase or rent additional acres than what they were managing at the time of the school. Approximately 45% of the respondents indicated that they had increased the number of clients as a result of the training received in Iowa Drainage School, while 23% indicated that they had not increased clients, and 34% indicated that the question did not apply to them. Approximately 35% of the respondents indicated that they had hired additional staff subsequent to the school while 37% indicated that they had not hired any additional staff with 28% indicating that the question was not applicable to them. Thirty-nine percent of the respondents indicated that they had purchased additional equipment consequently to attending the school while 35% had not and 26% indicating that the question did not apply to them. Overall, the Iowa Drainage School helped respondents increase the scope of their work either with increase in clients, service area, hiring of employees, and/or purchase of additional equipment.

When asked how many drainage designs had been developed by the respondents, on average in one year, 55% reported

developing between 1 to 5 designs, 29% reported between 6 to 10, and 16% reported developing over 11 drainage designs. Using the mid-point of each response category, the average number of designs developed each year was reported as 373. Using a nine-year timeframe within which all of the respondents had attended the school, the total number of designs calculates out to 3,357 (373 times 9). Fifty percent of the respondents reported serving between 1 to 5 clients per year, 26% reported between 6 to 10, 14% for 11 to 20, and 11% serving over 20 clients. The average number of clients being served by the respondents of the survey each year, using the mid-point calculation on the range, was 370. Using a nine-year timeframe within all of the respondents had attended the school, the total number of designs calculates out to 3,330 (370 times 9). The ratio of designs developed to clients served is close to 1 (373/370). Fifty-five percent of the respondents indicated that their design projects totaled less than 2,023 ha in size, 19% indicated between 2,024 and 4,047 ha, 11% indicated between 4,047 and 10,117 ha, and 15% indicated designing for over 101,118 hectares. The total hectares for which projects have been designed, were 424,124. The average project size, calculated using the total hectares and total projects designed (3,357), was 126 ha or approximately 312 acres. Respondents were further asked to share what percent of the projects they had designed were actually implemented by their clients. Fifty-three percent of the respondents indicated that 76% to a 100% of their designs were implemented whereas seventeen percent reported between 51% and 75%, twelve percent between 26% and 50%, and seventeen percent reported less than 10% implementation of their designs. The average implementation rate for the designs developed by the respondents, calculated using mid-points of each group, was 63%. In other words, approximately two-thirds of the designs developed actually get implemented, indicating that the design features of all proposed designs do not match up with the client needs or opinions.

Culturally common practices can influence what the clients want in their drainage designs and how the clients want them implemented. These practices can influence lateral and main sizes, depths of installation, outlet sizing, inclusion of an alternate drainage coefficient than recommended, and use of different drainage lateral spacing than recommended in the design process. Appropriate design practices were taught in the school for using the drainage guide, Le-Hoghoudt's drainage tile spacing equation, sizing of outlets, main, and laterals based on recommended drainage coefficient. The respondents of the survey were asked to share what percent of the designs developed by them actually made use of the design practices taught in the Iowa Drainage School. Forty-seven percent of the respondents reported that between 76% and 100% of their designs were based on the taught practices whereas twenty-seven percent reported between 51% and 75% of their designs followed practices taught in the school. Approximately twenty-six percent of the respondents indicated less than half of their designs followed the practices taught in the school. The average rate for the designs developed by the respondents to follow practices taught in the school, calculated using mid-points of each group, was 63%. In other words, approximately one-thirds of the designs developed followed one or more practices other than the ones taught in the school to meet client needs or opinions.

The question of use of design practices taught in the school was further explored in the survey. Respondents of the survey were asked to specify which practices for a better design they included in their drainage designs. Use of drainage coefficient to size the outlet, use of drainage coefficient to size the main, and depth & spacing of laterals such that drainage intensity matches the drainage coefficient, were reported by over 70% of the respondents as practices incorporated into their designs. Use of a land area survey to plan and layout the drainage design was reported being used by only 52% of the respondents. Availability of GPS-RTK surface elevation profiling software on some of the tiling plows limits the need to develop a complete land area survey. With the use of such software, operators of plows are able to control the depth of tile placement in relation to the surface elevation. In addition, availability of LiDAR derived contour maps, with 0.61 m (2-foot) contour intervals, can provide a general idea about how the topography will work in relation to the drainage design. It is, therefore, logical that a use of a land survey was reported by only one-half of the respondents. Sizing of the laterals using the drainage coefficient was reported by 62% of the respondents as a practice incorporated into the drainage designs. This number matches with the average rate of inclusion of design practices as described in the previous paragraph. It is common that 10.2 cm (4-inch) diameter drainage tubing is used where the design calls for a 7.6 cm (3-inch) or a 5.1 cm (2-inch) diameter drainage tubing. Drainage tubing manufacturing companies offer the 10.2 cm (4-inch) diameter tubing at a similar price to the other smaller sizes. In majority of the cases, the 5.1 cm (2-inch) drainage tubing is not even manufactured and can cost more than the 10.2 cm size due to custom manufacturing requirements. The use of larger size diameter laterals than what the design calls for, increases the drainage coefficient which can in turn overload the main drainage tile line. In these cases, the drainage spacing needs to be carefully evaluated.

The decision of what design to implement can further be influenced by the location of the land in terms of the drainage system connectivity with dominant and servient lands. Dominant lands are the ones where the drainage originates and servient lands are the ones where the drainage originating from dominant lands gets served upon. Majority of the lands are in dual status of being both servient and dominant lands. Such lands get drainage water served to them from the upper elevation dominant lands, and in-turn such servient lands then become dominant lands to serve the water they received plus the drainage water of their own to the lower elevation servient lands. Appropriate drainage for such lands depend upon the flexibility of the system to accommodate the current needs and the future expansions which may occur on the proposed land and as well as the dominant lands serving the proposed land. Respondents of the survey were asked to respond as to how many designs included working with dominant land owners and how many designs included working with servient land

owners. Thirty-one percent of the respondents reported between 11% to 75% of their designs included working with dominant land owners. Forty-three percent of the respondents reported between 11% to 75% of their designs included working with servient land owners. The average rate of having to develop designs by working with either dominant or servient land owners was 31%, calculated using the mid-points of the ranges reported. This average rate is close the number described earlier where one-third of the designs developed included practices to meet the client needs or opinions. These responses signify the results that the drainage designs are not just purely a science but also an art when it comes to design implementation on the landscape.

A second component of the Iowa Drainage School has been inclusion of drainage water quality best management practices of controlled drainage and shallow drainage into the drainage designs. When looking into designing shallow drainage as a water quantity and quality management practice, 71% of the respondents indicated that none to less than 10% of their designs included shallow drainage. Twenty-seven percent of the respondents indicated that 11% to 75% of their designs included reduced drainage tile depths. Only seven percent of the respondents reported inclusion of shallow drainage in over 75% of their designs. A similar trend of low adoption of a control structure for drainage water management was reported by the respondents completing the survey. Fifty percent of the respondents indicated that none of their designs included a control structure, whereas an additional 39% of the respondents indicated that less than 10% of their designs included a control structure. Overall, close to 90% of the respondents reported very low adoption of the concept of drainage water management using a control structure. Low adoption of these water quality practices by contractors could be an indicator that both contractors and land owners are still not fully aware of the benefits and additional training is required. A second potential reason for low adoption of drainage control structures is that Iowa's rolling topography does not lend itself to installation of this drainage water management system. Multiple control structures may be required to manage the slope changes which adds a significant cost to the drainage system. Respondents were also asked to identify future needs on different drainage topics. Sixty-four percent of the respondents indicated that they will like to get training on controlled drainage, 57% on bioreactors, 53% on saturated buffers, 35% each on drainage laws & shallow drainage, and 27% wanted additional training on wetlands. These results are in line with what has been observed in the school. Design of wetlands is a complex process and is likely to be of interest to service providers and consultants. From a contractor standpoint, design of controlled drainage, bioreactors, and saturated buffers is relatively more important due to the work performance and economic opportunities these practices produce. Farmers and land owners are likely to be more interested in the drainage laws as the laws bring restrictions and uncertainty to the drainage topics.

## Conclusions

Farmland drainage is an integral part of Iowa's landscape and plays a critical role in its bio-economy. Production capacities of Iowa soils can only be optimized with well-designed and properly operating subsurface drainage systems. Iowa State University Extension & Outreach has conducted the Iowa Drainage School since 2007 to educate stakeholders on subsurface drainage concepts customized to the upper Midwestern states. The follow-up survey of the participants attending the school in the past nine years reveals that the overall impact of the Iowa Drainage School has been positive and continued education is required. The usable responses were received from 34.8% (74/207) of the total participants contacted. These respondents consisted of producers (31%), service provider i.e. consultants (12%), contractors (54%), and others (4%). Close to 80% of these respondents had attended the school within the last four years. The summary of these responses supports the following:

- As a result of the training in the school, 45% of the respondents indicated an increase in number of clients they served, 35% of the respondents indicated hiring additional staff, and 39% indicated purchasing additional equipment to manage the additional work acquired.
- Respondents reported developing a per year average of 373 drainage designs for a per year average of 370 clients served with an average project size of 126 ha or 312 acres. Respondents reported that approximately two-thirds of the designs they developed actually get implemented, indicating that the design features of all proposed designs do not match up the client needs or opinions.
- The average rate for the designs developed by the respondents using the knowledge gained from the school in terms of lateral and main sizes, depths of installation, outlet sizing, inclusion of drainage coefficient, and use of lateral spacing taught in the school, was 63%.
- The average rate of developing drainage designs by working with either dominant or servient land owners was 31%. This average rate is close the number described earlier where one-third of the designs developed included alternate practices necessary to meet the client needs or opinions. These responses signify that the drainage designs are not purely a science but also an art when it comes to design implementation on the landscape.
- Low adoption of a control structure or shallow drainage for drainage water management was reported in the survey. Low adoption of these water quality practices is an indicator that both contractors and land owners are still not fully aware of the benefits and additional training is required.

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## Nomenclature

DC – Drainage Coefficient  
IRB – Internal Review Board  
NASS - National Agricultural Statistics Service  
NRCS – Natural Resource Conservation Service  
ORR – Office of Responsible Research  
QADCA – Québec Agricultural Drainage Contractors Association  
USDA – United State Department of Agriculture