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## Vegetative Environmental Buffers for Odor Mitigation

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### Introduction

An odor mitigation technology that is drawing a lot of attention in Midwestern livestock producing states is the strategic use of shelterbelts – purposefully planted trees and shrubs arranged in linear patterns around production facilities; a technical term for this technology is Vegetative Environmental Buffers or VEBs. Research suggests that VEBs can play an important, incremental low-cost role in bio-physically and socially mitigating odor.

### Objectives

The objectives of this fact sheet are to:

- Characterize the role that Vegetative Environmental Buffers (VEB) can play in livestock and poultry odor mitigation
- Overview VEB design considerations
- Overview the financial aspects of using VEBs

### Background

Vegetative Environmental Buffers have been shown to incrementally mitigate odors by interacting with particulates, volatile organic compounds and ammonia through a complex of bio-physical dynamics [1-3]. Among the most important dynamics are: 1) enhancement of vertical atmospheric mixing through forced mechanical turbulence which enhances dilution/dispersion of odor; 2) odor filtration through particulate interception and retention; odor largely travels by way of particulates, therefore, managing particulates aides in the management of odors; 3) enhanced odor/particulate fallout due to reduced wind speeds near and downwind of the VEB; and 4) adsorption and absorption of ammonia onto and into the plant – this is largely due to a chemical affinity that ammonia has to the waxy coating on tree leaves.

Furthermore, because VEBs can improve site and landscape aesthetics and create “out of sight, out of mind” situations, they have been noted for their capacity to soften “visual cues” of odor (e.g., the physical appearance of a production site), thereby positively impacting socio-psychological responses to odor [1]. VEBs might also contribute to improved producer/community relations because they are a highly visible odor management technology whereas many other mitigation approaches are not directly observable.

The physical effectiveness of VEBs in mitigation is extremely site specific and ultimately a function of a myriad of factors: VEB design, ambient weather conditions, landscape topography, direction and distance to nearest critical receptor (e.g. neighbors, communities), scale of emissions, and the manure management protocols followed and other odor mitigation management utilized. Because of this, the quantification of odor mitigation via the use of VEBs is a very difficult process. Quantification of odor mitigation is approached in a multi-analytic way by means of field trials, wind tunnel

examinations and computer simulation. Field quantification, as one would imagine, is particularly difficult and explains the general scarcity of field-scale data [4]. Still, a few field studies have recorded incremental mitigation benefits in the form of reduced particulate and odor movement downwind due to the presence of VEBs/ windbreaks. For example, at two separate 8-barn swine finisher sites in Missouri, researchers found that in comparison to a control site, a simple VEB reduced odor concentrations (Dilutions to Threshold, D/T) by almost 50% in the VEB and by two-thirds at a distance of 15 m downwind of the VEB (a statistically significant finding) [5]. Lin et al. [2] describe field data that shows under variable atmospheric conditions windbreaks can reduce what is called the “maximum odor dispersion distance” (MODD) or the distance required to dilute odor below acceptable levels (this distance is often a general criteria for determining legal separation distances). According to this study, depending on air temperature, wind direction and speed windbreaks reduced MODD at field sites by up to 40% [2]. For certain constituents of odor, however, such as odorous gases (e.g. H<sub>2</sub>S) the downwind effects of windbreaks are not always consistent. For example Hofer [6] measured decreasing effectiveness of a VEB in terms of H<sub>2</sub>S concentration at downwind distances greater than 500 m. Along with field level data, various laboratory and/or otherwise experimental research has pointed to odor mitigation outcomes due to VEBs. Wind tunnel and computer simulations have quantified reduced particulate and odor movement due to the presence of strategically located trees [7,8]; for example, at Iowa State University, Laird [7] recorded via wind-tunnel modeling a 56% reduction in simulated off-farm dust movement.

## Limitations of VEBs

From an odor mitigation perspective, site-specific VEB design is of critical importance. There is a distinct difference between a production site that has a strategically designed VEB and a site that simply has “trees on it” (e.g., for landscaping purposes). As noted, studies have shown that strategically placed trees have a beneficial physical impact on downwind odor, whereas trees used simply for visual landscaping or are naturally part of the landscape may not [9]. While VEBs have been shown to contribute incrementally in reducing the downwind concentrations of particulates and odorous chemicals, what this means to the highly subjective perception of odor as a “nuisance” is a very difficult question to answer. The benefits of the incremental contribution of VEBs to odor reduction are likely to be found in variously reducing the combined effects of the FIDO factors of odor events – the frequency, intensity, duration, and offensiveness of odor. Simply put, the use of VEBs is not a substitute for comprehensive odor management strategies - rather their use should be thought of as complimentary technology within a “suite” of odor management strategies [1].

## Applicability of VEBs

As an odor mitigation technology VEBs have advantages over many other approaches in terms of application. VEBs are a species neutral technology. While VEBs have been examined primarily in swine and poultry contexts, e.g. swine: [1, 5]; poultry: [10], they have also been recommended for dairy producers [11]. VEBs are adaptable to the landscape of different livestock production sites and production regions and are amenable to use near or around all sources of livestock odors (e.g. animal buildings, manure storage areas, and crop land receiving manure applications). A VEB is a technology that can be considered facility neutral, in that producers who raise animals in confinement (mechanically or naturally ventilated), hybrid confinement, hoop house, pasture—can utilize VEB systems. The presence of trees in agricultural landscapes has socio-aesthetic advantages that most other odor mitigation technology lack completely. VEBs are a size neutral odor mitigation technology; that is, producers of all scales can plant trees. Furthermore, many odor mitigation technologies tend to depreciate over time with an accompanying increase in maintenance requirements and cost, VEBs on the other hand may be the only odor control technology that (theoretically) improves in effectiveness over time thus increasing cost efficiency. As the trees grow larger and more morphologically complex their ability to mitigate odors through particulate filtration and mechanical turbulence should increase up to a point. Of course, any increase in mitigation effectiveness over time is contingent upon the long term-health and maintenance of the VEB system and continuance of appropriate manure management.

## Implementation

When implementing a VEB, there are several key design issues. A proper VEB can serve as both a visual screen and an odor filter. To this end, one needs to account for prevailing summer and winter winds and key visual pathways (e.g., screening a manure storage area from passing traffic). Key planting zones can then be identified so as to maximize the effects of filtration and increased turbulence and provide screening from desired angles and directions. Specific planting guidelines such as location of plantings, total number of trees, spacing between trees and tree rows and so on, depends upon available space, the species chosen and the functional goals of the VEB. Determining appropriate species depends

upon their functional role but is also a region specific issue (e.g., plant hardiness) as well as adaptability to site conditions (particularly soil conditions). It should be noted that a number of studies have indicated that conifers appear to be marginally better than deciduous trees in mitigation capacity [e.g., 1, 2]; this is likely due to an increased “dust-collecting” surface area that conifers possess relative to deciduous trees as well as year-round leaf area. Spacing between trees strongly depends upon the functional goal as well as tree location on the site. Studies have shown that VEB porosity (degree of VEB openness relative to total area) plays a role in turbulent transfer of odor as well as particulate filtration. VEB porosities of 35-50% have been cited to have the greatest impact on the degree of turbulent transfer, extent of reduced wind speed, and extent of odor plume exposure to foliar surface area [1, 2, 6]. Ultimately it is always recommended that a producer seek direct advice from a forestry or nursery professional who is familiar with VEBs before proceeding. There are a number of VEB planting, design and management guides available to producers interested in exploring the technology, e.g., [12,13].

There are three main hazards that must be avoided when utilizing VEBs. First, buffer designs need to prevent winter snow deposition problems caused by planting trees too close to access roads and buildings. In Central Iowa, for example, winter winds largely come from the North/Northeast. Therefore VEBs planted to the north of buildings/roads should plan for a planting distance anywhere from 50-200’ away. Secondly, trees should not be planted so close to buildings that they prevent appropriate air flow into and out of the buildings. For mechanically ventilated buildings trees can be planted as close as 5-6 times the diameter of the fans and avoid causing back pressure, yet that distance may not be healthy for the trees [1]. Based on field trial experiences, a distance of at least 40 feet away from fans has been recommended to avoid tree desiccation [10]; other studies however have noted planting distances in the 30 foot and less range with deliberate fan deflection directly into vegetation without evidence of compromised plant health [5]. Ultimately optimal planting distance is likely site specific and contingent upon site conditions, management and the tree/shrub species planted. For naturally ventilated systems, it is important not to impede necessary summer winds from ventilating the buildings (in Central Iowa prevailing summer winds tend to come from the South/South east). Finally, traffic visibility into and out of the facility grounds is important, therefore the mature heights and canopy shapes of trees need to be considered when planting trees near access roads. See Figures 1a,1b,and 1c below for an example VEB design.

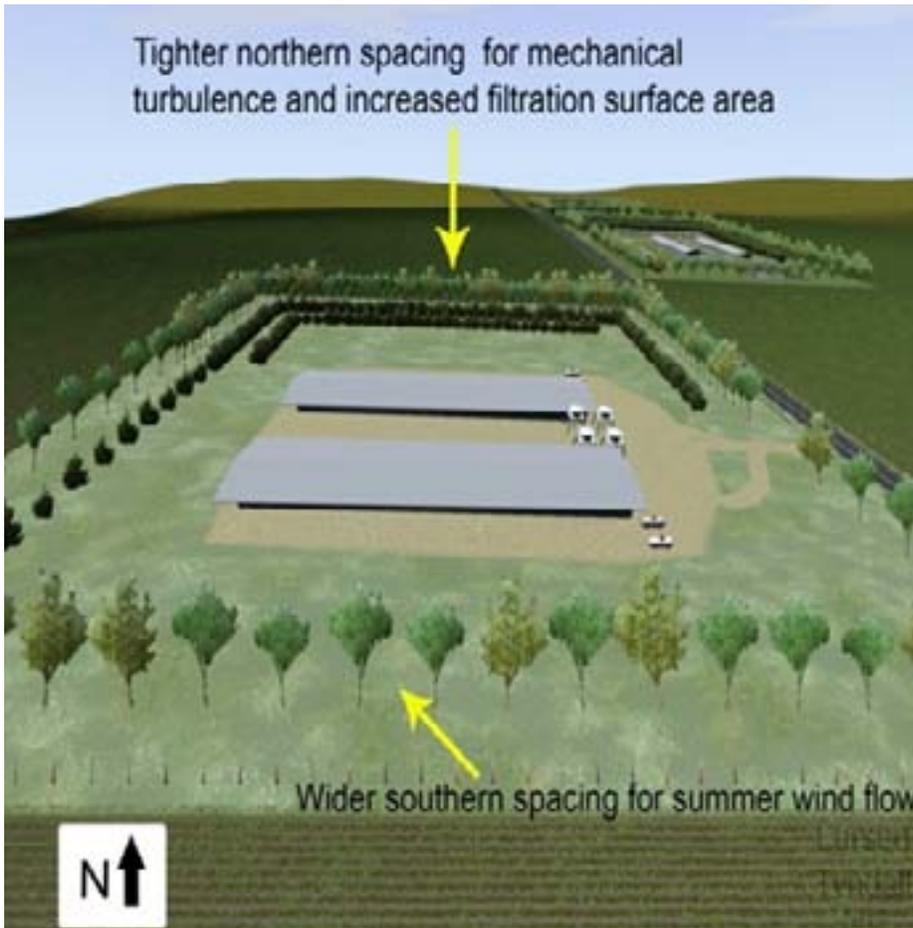


Figure 1a

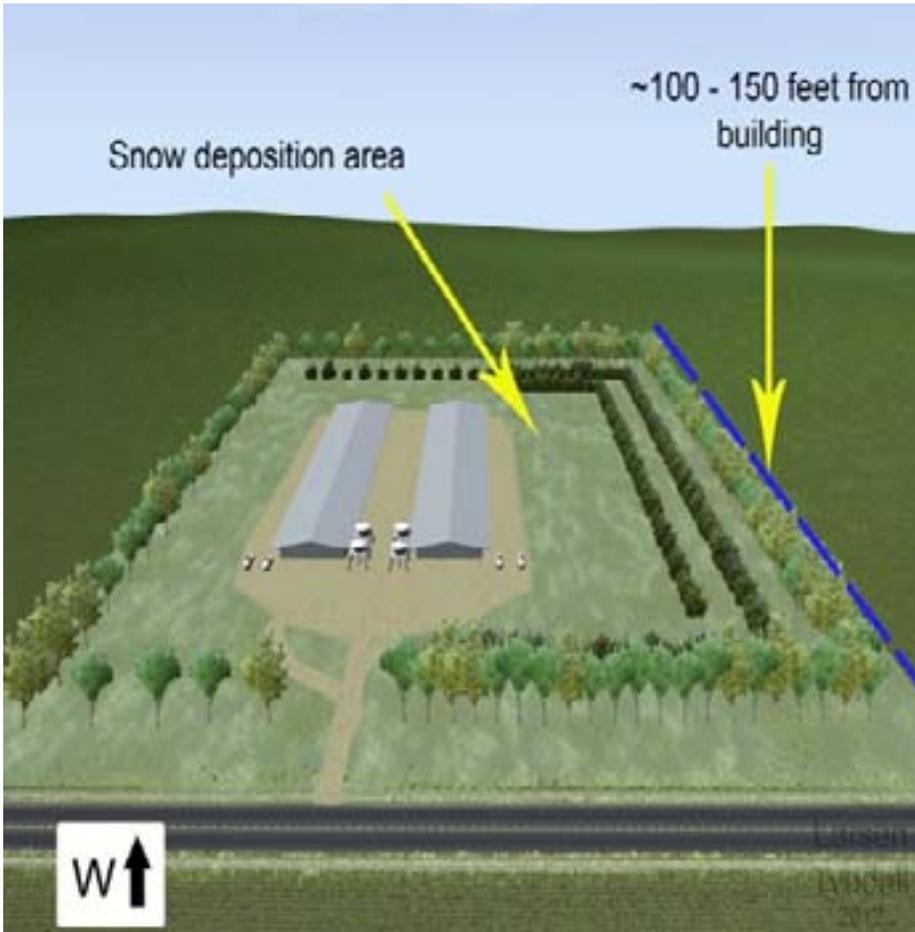


Figure 1b

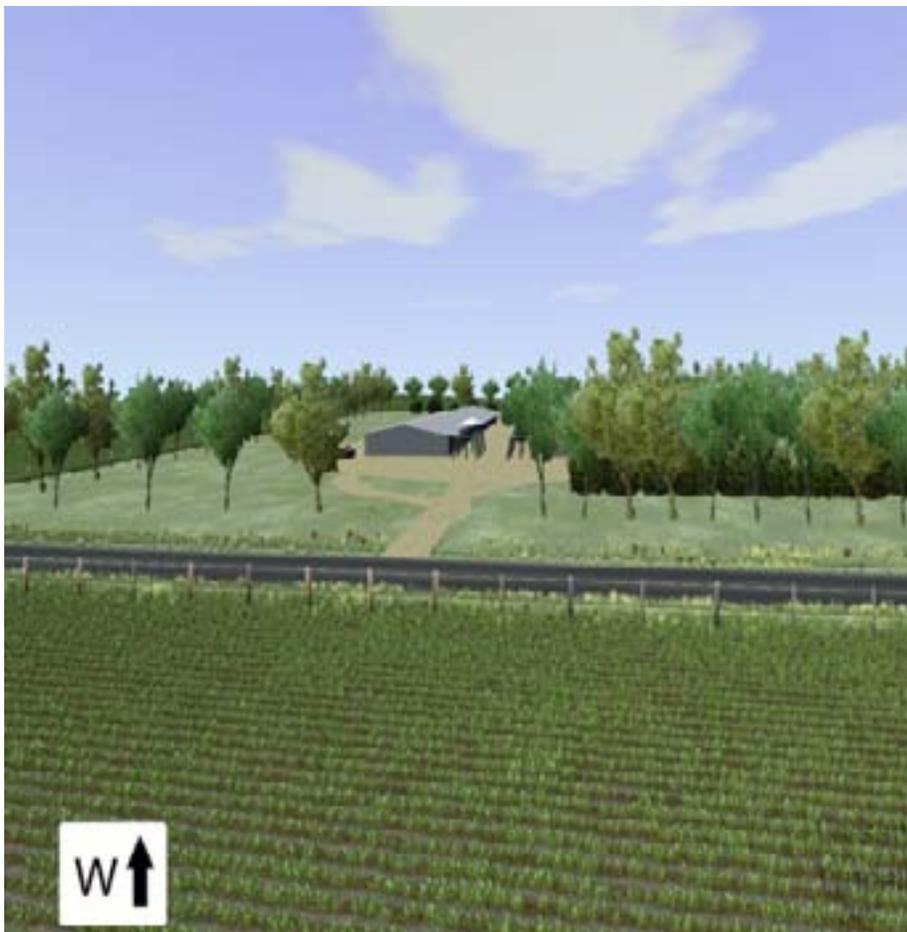


Figure 1c

Figures 1 a, b, and c. Example general VEB design for a two building, naturally ventilated swine finishing unit. VEB is designed with Central Iowa wind patterns in mind. 1a. North-facing view showing variation in tree spacing to achieve certain outcomes. 1b West-facing view showing snow-deposition zone. 1c. West-facing view from the road. Ultimately VEB designs (e.g. planting patterns, locations, species used) will be variable and site specific. Visualizations created by G.L. Drake Larsen.

All VEBs need to be established in appropriately prepared planting areas using regionally appropriate nursery stock. All VEBs should have a well thought out long-term maintenance plan to ensure the overall health of the systems and to keep long-term costs/labor requirements down. Another key design factor is mixing the species used. This is recommended for two main reasons: 1) increased species diversity reduces the risk of whole scale pest/pathogen loss, and 2) some species (e.g. hybrid willows and poplars) feature very rapid growth but often have relatively short healthy life spans (e.g. 15-20 years). Mixing in slower growing but longer-lived species will allow for a robust and mature VEB system to remain after other species are removed.

Appropriate site preparation is one of the main keys to the long-term health of tree plantings and will contribute toward lower tree mortality, faster tree growth and, ultimately, lower time, money and effort in managing the system over life of the operation. In many cases the grounds of a confinement livestock facility - the area where trees are to be planted - feature highly compacted soils, subsurface soil piling, poor drainage, etc. The risk of VEB failure (due to poor tree health) will increase significantly with inadequate site preparation. If planting trees directly into recent crop ground, site preparation requirements will likely be minimal. Table 1 below outlines possible requirements.

1 Year before VEB establishment (Fall: October-November):	Year 1 (Spring-Late April/Early May)
4' Kill strip (e.g. Round Up)	Disk/cultivate again & if possible rototill
Disk/ cultivate (work soil to 8" depth)	Soil should have no clumps & minimal residue
Seed cover crop (e.g. clover, rye)	Grass seed may be desired (sow outside of mulch and or weed mat zones)

Table 1. Generalized site preparation requirements for new livestock facilities

## Costs

Costs for VEB systems are highly variable and site/VEB design specific – but for most production systems, VEBs cost just a few cents per animal produced. There are four main categories of expenses associated with VEBs: 1) Site-preparation costs; 2) tree establishment costs which includes purchasing tree stock and planting costs; 3) long-term maintenance costs which include weed control and periodic site mowing; and 4) any opportunity costs such as the cost of capital and, if required, land rent costs. “Upfront” costs tend to be 30% to 45% of the total cost of utilizing a VEB and is tied to the cost of the initial planting stock (some producers may choose larger nursery stock which can be considerably more expensive than bare-root seedlings but such an investment may “buy time” by jump starting VEB development). Long-term maintenance costs, such as for regular mowing (e.g., between trees and rows) and periodic tree replacement vary depending upon the overall health of the VEB. A degree of tree mortality is likely and upwards of 25% tree loss during the first 5 years after planting is not uncommon. It should be recognized that while there are expenditures that occur regularly throughout the life of a VEB, as a VEB system matures the annual maintenance requirements will likely decrease. Below in table 2,

the results of an Iowa wide VEB cost assessment are presented. The cost data comes from a study of VEB designs created for a random, but regionally stratified selection of 100 hog production facilities in Iowa [adapted from 15]. Site prep, VEB establishment and management costs were assessed over a 20-year period for all individually designed VEBs and averaged for the state.

Total annualized expenses, depending upon the cost of the planting stock ranges from \$85/year to about \$360/year. About 44% of total 20-year cost occurs in the first 2 years of establishment. Because upfront costs can be substantial, cost share programs may be of interest for many producers. A program such as the Environmental Quality Incentive Program (EQIP) can reduce the total costs upwards of 40% to 50%. Currently in Iowa the NRCS is paying producers up to \$862 per acre to plant VEBs around livestock production sites [14].

It should be noted that ultimately the total costs of VEBs are contingent upon the initial choice of planting stock, the relative long-term health and maintenance of the system, and the choice of long term weed control (i.e. chemical or mechanical weed elimination; use of organic or synthetic mulches, etc.). With drier soils a drip irrigation system may be necessary and would add roughly \$0.01/ per pig produced.

Table 2. Annualized cost of VEBs over a 20-yr period (2012\$). Assessed at a 4% real discount rate. Data updated from [15].

VEB Cost Assessment (2012 averages for Iowa)	Cost without EQIP <sup>4</sup>	Cost w/EQIP <sup>4</sup>
Annualized Costs "Low price" <sup>1</sup>	\$85	\$30
Upfront costs only – "Low price" <sup>2</sup>	\$750	\$0
Annualized Costs "High price" <sup>1</sup>	\$360	\$295
Upfront costs only – High Price <sup>2</sup>	\$3,400	\$2,300
Annualized costs per pig produced <sup>3</sup>	\$0.01 – 0.03	< \$0.01 – 0.02

<sup>1</sup> Low price scenarios: 15" cuttings of Austree = \$1.00/tree; 12"-18" Eastern red cedar = \$ 2.50/tree, 12"-18" red osier dogwood = \$1.50/shrub; High price scenarios: potted Austree = \$ 7.50/tree; 18" – 24" potted Eastern Red cedar = \$ 12.50/tree, 4-yr Red Osier dogwood = \$3.50/shrub. Planting costs are also higher for the high price scenario. Choice of tree species will normally vary from site to site. Costs do not include land rent; though it should be noted that the 2012 average Iowa land rental rate was \$254 per acre.

<sup>2</sup> Includes only the costs for site preparation, tree stock, VEB establishment,(planting, initial watering)

<sup>3</sup> Production capacity was estimated by the dimensions of production buildings and assuming 2.2 turns of animal stock per year.

<sup>4</sup> Environmental Quality Incentive Program parameters were modeled assuming the current maximum Iowa VEB payment of \$862 per acre.

## Summary

Tree-based Vegetative Environmental Buffers (VEBs) can be a cost-effective way for livestock producers to incrementally mitigate odors, particulates and ammonia emanating from their sites. As air moves across vegetative surfaces, leaves and other aerial plant surfaces remove some of the dust and odorous constituents of airstreams while increased mechanical turbulence can boost the vertical mixing of air streams thereby enhancing the dilution of odor plumes. VEBs are relatively inexpensive and straightforward to manage and therefore in many cases can easily fit into current odor management plans. While the physical effectiveness of a VEB in mitigating odors and the overall expense of establishing and managing a VEB are variable and site specific, their use can incrementally enhance a livestock production system's ability to reduce negative odor impacts for just a few cents per animal produced.

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