ACID SOIL ACTION
An Initiative of the NSW Government

The Acid Sulfate Soils Drainage Guidelines as a component of the ASS Manual form part of an ‘all of government’ approach to the management of acid sulfate soils in New South Wales.

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These guidelines should be referred to as:

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About the guidelines
The Acid Sulfate Soils Management Advisory Committee (ASSMAC) was formed in 1994 to coordinate a whole of government response to acid sulfate soil issues. The committee reports to the Minister for Agriculture and comprises representatives of NSW Agriculture, Department of Land and Water Conservation, Department of Urban Affairs and Planning, Environment Protection Authority, NSW Fisheries, Local Councils, the scientific community, NSW Fishing Industry, NSW Farmers Association and the Nature Conservation Council.

The ASS Manual developed by the Acid Sulfate Soils Management Advisory Committee Technical Committee (ASSMAC TC), provides advice on best practice in planning, assessment and management of activities in areas containing acid sulfate soils. The manual also provides advice on best practice in drainage, groundwater monitoring and management as well as the management of sugar cane and tea tree farming in acid sulfate soils.

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1. INTRODUCTION

Drainage in coastal areas for agricultural, industrial or urban development requires extreme care because large tracts of estuarine land are underlain by acid sulfate soils. Over the last hundred years, many of the low-lying coastal areas have been drained for agricultural or other purposes. Many of the larger drains were dug as part of back swamp drainage programs at the turn of the century. Other major drains have been dug and maintained by drainage unions over the last 50 years. In addition major drains and levees which have had major impacts on the hydrology and acid sulfate soils were developed for flood mitigation in the 1950s to 1970s.

1.1 Problems with drainage in acid sulfate soils

The draining of low-lying land has enabled landowners to grow crops and pastures with varying degrees of success. However, in many areas the drainage has resulted in the lowering of the watertable, with the land becoming acidified, loosing productivity and in extreme cases becoming scalred and an environmental hazard. The water draining from these soils can be extremely acidic. Potential sources of acid include:

- **surface run-off of acid water from the acidified land.** As the drain can lower the watertable, the iron sulfide layer in the adjoining land can dry out and produce acid even though the land itself has not been disturbed. This can also happen in droughts when the watertable drops. With rain the acid washes into the drain.
- **acid groundwater seepage** through the drain wall into the drainwater from land that has been drained and acidified.
- **the excavator digging into the iron sulfide layer** and piling the material on the side of the drain during construction. The acid sulfate soils exposed on the walls of the drain and in the spoil layer can become extremely acidic and leach acid water into the drains. As vegetation will not establish on these spoil heaps beside the drains, the sulfidic sediment can also erode back into the drain.
- **drain maintenance** resulting in sulfidic material being scraped up when weeds and sediment are being cleaned from the drain. When these are left on the sides of the drains, they acidify and leach acid water as well as nutrients back into the drain.

1.2 Why drain?

Heavy rainfall events can result in water in excess of the plant’s requirements with the soil profile filling until the soil is saturated. The longer the water stays on the surface, the more likely the pasture or crop will suffer. When soils become waterlogged, water replaces the air in the soil profile. Root growth is shallow and less density or they get root rot, resulting in reduced crop respiration, nutrient uptake and slower growth. Waterlogging can reduce crop productivity by 20%, often without detection. Waterlogging of pastures can lead to a change of composition with the invasion of rush and other undesirable plans.

While drainage systems may be essential for coastal landowners to continue to earn their living from the land, the drains should be carefully designed and managed to ensure the long-term productivity of the land and continued health of the associated waterways. Over draining and poorly designed drains can permanently damage the land and lead to the loss of productivity and property value. Many areas of valuable drought reserve have been drained and ruined for grazing or any other agriculture purpose because acid sulfate soil issues were not understood.

Because of the risks to the environment and the productivity of the land and rivers, there must be a very strong justification for the construction of any new drains or the deepening or extension of any existing drainage works. A preference should be given to the reduction in the number and depth of
drains and wherever possible a reconfiguration of existing drains to reduce the impact on the environment.

When planning where drains should be located and considering their design and management, it is important to understand where the water to be exported is coming from and why it needs to be removed. Is the water originating from the property (from say from a 2-year flood), or from rising groundwater or from the upper catchment with large volumes of water passing across or backing up onto the property only during larger flood events. The drainage strategy to deal with each of these types of situations may need to be different.

The drains need to be carefully designed to achieve the particular flood or storm water performance objectives without causing an acid sulfate soils problem. The depth of the drain will also be influenced by the proposed land use. However the landowner should also consider the constraints associated with the presence of acid sulfate soils when deciding on the future use for their land. About 30 per cent of all NSW caneland is now landformed with the drains redesigned. This has resulted in many field drains being filled in with the advantage of extra rows being available for planting and the drains managed to reduce the export of sulfuric acid generated by oxidisation.

As there may be good quality native swamp pastures that will tolerate waterlogging, drains may not be required at all for some grazing country particularly if there is high land (natural or built) for the animals. Improved beef and dairy pasture generally require 30 – 60 cm of soil above the watertable and will tolerate up to two days waterlogging. For example, the production of pasture crops such as ryegrass, kikuyu, clover or cough will not be affected if the watertable is maintained at a maximum of 50 cm to 60 cm below the soil surface. Sugar cane has in the past, been thought to require up to 120 cm freeboard, but research is now demonstrating that less freeboard is well tolerated. As it is a native swamp species, tea tree will tolerate quite a high watertable.

Figure 1.1  Drains using natural drainage lines
2. Approvals to construct drains

2.1 Consult with council

Before undertaking any drainage works, it is essential that the landowner checks with the local council about whether any approvals may be required (see Figure 2.1). The Assessment Guidelines of the ASS Manual outlines when works which disturb acid sulfate soils are likely to require consent. All government agencies, county councils, drainage unions and councils undertaking new drainage works or changing or maintaining existing drainage works must consider the likely implications of their actions and in most cases prepare a management plan prior to undertaking these works.

Irrespective of whether approvals are required or not, as best practice, the environmental impacts of the drains or any earthworks in acid sulfate soil areas should be assessed and an environmental management plan developed in accordance with the ASS Manual before they are undertaken.

Drainage unions, county councils, councils as well as individual property owners may need to lodge a development application with council before commencing any drainage work.

If the drain affects a wetland mapped under SEPP 14 – Coastal Wetlands, then development consent is required from council and an environmental impact statement must be prepared.

2.2 Consult with government agencies

There are other approvals that may also apply. When constructing or maintaining major drains or undertaking dredging or reclamation works, an approval may be required from the Minister for Fisheries under the NSW Fisheries Management Act. This provision does not apply if the works are authorised by a relevant public authority or under the Crown Lands Act 1989. If the works are within 40 metres of a natural creek or river, an approval may be required under the Rivers and Foreshore Improvement Act from the Department of Land and Water Conservation (DLWC). If a drain crosses a public road, permission may be required from DLWC or from council. Approvals may also be required under section 68 of the Local Government Act, for example, if a private drain connects to a public drain or if the works are considered to be stormwater drains. In some circumstances, the Protection of Environment Operations Act, Coastal Protection Act 1997 or Native Vegetation Conservation Act (1998) may also apply. Check with both the local council and relevant government agencies before doing any works.

2.3 Consult the neighbours

Changes to farm drainage can affect the environment and have positive or negative effects on adjoining landowners’ properties. It is important to consult neighbours and other landholders and any catchment management committee prior to undertaking any drainage works which may have impacts on the catchment or other property owners. In many cases, surrounding landowners may be able to undertake joint drainage projects with the advantage that a more strategic approach can be undertaken to improving the drainage management in the subcatchment. In these circumstances joint applications can be made to councils and other agencies streamlining the assessment and approval process.
Figure 2.1 Dealing with Drains in Acid Sulfate Soils

**Is a drain required?**
- needed as part of catchment, flood or drainage scheme?
- affecting groundwater levels or nearby wetlands?
- affecting the water quality in the creek?
- reducing/increasing the productivity of the land?
- affected by floodgates? are they maintained?

**Is the drain still required?**
- No
- Not sure
- Yes

**Is the drain legal?**
- does the drain affect SEPP 14 Wetlands? Was DA approved?
- was the drain constructed prior to the planning approvals being required? If require, was a DA approved under the LEP?
- Were relevant approvals/licence gained from council, DLWC, NSW Fisheries or EPA?
- was a Part 5 assessment required and undertaken?

**Is the drain lawful?**
- Check with councils

**As part of the property/farm management plan, integrate into the management of the property the filling in of drains as soon as possible**

**Does the drain need changing or enlarging?**
- No
- Yes

**Does the drain need cleaning only?**
- mechanically remove plants
- chemically remove plants
- mechanically remove soil & plants

**Are other approvals required?**
- Fisheries Management Act, Local Govt Act, Rivers and Foreshore Improvement Act, Native Vegetation Act, Protection of the Environment Act?

**Are other approvals required?**
- No approval required
- Obtain licence
- May need to lodge a DA with council
3. Principles for drainage in acid sulfate soils

When designing drains, the relationship between surface and subsurface drainage should be considered. Drains can collect surface, as well as ground water depending upon the depth of the drain and the topography. The drainage system may need to consider a combination of:

- surface drainage to remove flood and storm water
- subsurface drainage to manage waterlogging and intercept subsurface flows
- levees to divert or contain flow
- landforming to increase the efficiency of drainage or irrigation systems.

The following generally objectives should be met for existing drain or new drains unless there is research to demonstrate that an alternative strategy is preferable:

- to maintain the ground watertable at or above the sulfidic sediment.
- to prevent waterlogging and remove excess water within a reasonable period of time
- to ensure that any acid produced as a result of drainage is responsibly managed in accordance with the Management Guidelines in the ASS Manual.

Rules of thumb

Once the presence and depth of sulfidic sediment has been determined from the Acid Sulfate Soil Risk Maps and preliminary soil assessment, and then from a series of tests boring over the site (see the relevant section in the ASS Manual), a number of general principles should apply.

1. Where areas are “scalded” or degraded and devoid of vegetation, no further drainage should be undertaken. Remediation strategies should be developed which may include alternative drainage management including the removal of existing drains.

2. Where the sulfidic layers is at a depth below the soil surface of less than 0.5 metres, these areas should be left undrained as any drainage will produce acid. (White et al 1997). Generally these areas are best-left waterlogged and planted with species such as swamp grasses.

3. Where the sulfidic layer is between 0.5 and 2.0 m from the surface, drainage should only be attempted with properly designed drains and treatment of any acidic discharge.
   - if the sulfidic layer is 0.5 to 1 metre below the soil surface, then surface drainage and landgrading should be limited to cuts less than 30 mm. Irrigated pastures or crops should be considered.
   - if the sulfidic layer is 1 metre to 1.5 metres below the soil surface, then surface drainage and landgrading should be limited to cuts less than 0.5 m. Subsurface drainage may also be possible in heavy clay soils and should be limited to 0.5 m depth.
   - if sulfidic layers more than 1.5 metres below the surface, surface drainage, subsurface drainage and landgrading should be limited to cuts no greater than 1 metre.

In specific situations, variation from the “rule of thumb” will only be justified if a full environmental assessment has been undertaken by a suitably qualified consultant and a plan of management prepared demonstrating that an acid sulfate soils problem will not result and that any potential impacts can be managed. However, the drainage design should avoid drainage of soil layers that contain deposits of jarosite. Jarosite is a store of acid. Any drainage of jarositic soil will result in acid drainage waters.

Drainage design is a developed engineering practice in which crop, soil and climatic factors are combined to calculate drainage requirements. It is important to seek advice from qualified drainage specialists before commencing drainage works.
4. Drainage of storm and flood water

Drainage design is acid sulfate areas should use wide shallow drains which meet the following criteria:

- Large enough to remove excess storm or flood water from the area within 2 days
- To prevent erosion, the grade should be between 1 in 600 and 1 in 2000 with design velocities less than 0.6 m/s for loam and silty soils and less than 1.2 m/s for clay and gravel soils
- Designed to have a minimum impact on farming operations

Figure 4.1 Cross section of a trafficable field drain

4.1 Average runoff

A drainage system is designed to remove excess rainfall (runoff) within a specific period of time. The approximate volume of runoff can be calculated using the following formula.

\[ V = K \times R \times A / 100 \]

where
- \( V \) = volume of runoff in megalitres
- \( K \) = runoff co-efficient which varies from 0.5 for well drained loam soils to 0.7 for heavy clay soils
- \( R \) = rainfall for the selected inundation period in (mm).
- \( A \) = catchment area drained in hectares

The value of \( R \) (rainfall for selected period) depends on the selected period of inundation.

The maximum 24 hours rainfall for the highest daily rainfall event for the last 30 years of rainfall data should be determined from available data (longer if data is available) and ranked in order of magnitude. The 24-hour rainfall event with a 1 in 5-year probability should be selected. If the selected period of time \( T = 48 \) hours then the 1 in 5 year probability is determined for a two day rainfall event.

4.2 Peak storm Design

The peak storm design criteria should be used for high value crops or crops susceptible to water damage and for industrial development or urban development. The design is determined by using the Intensity/Frequency Duration Design Rainfall in accordance with the algebraic procedures presented in “Australian Rainfall and Runoff” (1987). Generally a 1 in 5 year to 1 in 20 year probability rainfall intensity is adequate depending upon the situation.
As most crops can withstand some form of inundation, the drainage need not be designed for a peak storm. Designing for an average runoff storm is adequate. However peak storm design may be applicable for high value crops or drainage for industrial or urban development.

4.3 Drain dimension

To design the drain, a detailed landscape and soil survey of the area to be drained should be undertaken. This survey should indicate the slope, the soil layers and their characteristics and the depth to the sulfidic soils (See ASS Manual). An estimate of the volume of the water to be removed from the site is also required. The following formula can be used to calculate the required drain capacity.

\[
Q = \frac{1}{n} \times A \times R^{2/3} \times S^{1/2}
\]

where

- \( Q \) = Drain capacity in cumecs (\( m^3/s \))
- \( A \) = Area to be drained in hectares
- \( R \) = Hydraulic Radius which is equivalent to the cross sectional area of the drain divided by the wetted perimeter of the drain
- \( S \) = Slope of the drain (usually between 1 in 600 and 1 in 2000)
- \( n \) = roughness co-efficient for various types of drain surfaces. 
  Generally \( n = 0.04 \) for well grassed drains and \( n = 0.02 \) for bare earth drains

The base width of most major drains should be no less than 3 metres wide. This allows construction by a scraper. Side slopes greater than say 5:1 will resist erosion where the runoff enters the drains from the side and allows machinery to cross drains. This also allows the drains to be slashed and maintained. Where the drain is along a fence line the side batter against the fence may be 2:1.

Figure 4.2 Drains in flat country
5. Drainage of sub-surface water

Sub-surface drainage is mostly used in conjunction with surface drainage or landforming to lower the water level beneath the root zone of the crop and improve productivity. Subsurface drainage should generally not be considered in pyritic sediment. Where the depth of overlying material is deep enough to permit subsurface drainage the drains should be placed so as not to lower the watertable below the pyritic sediment.

5.1 Maintaining high watertables

The watertable in some areas may need to be “artificially” maintained above the sulfidic layer during drought conditions or periods of excess crop water usage to reduce or prevent oxidation. A series of simple piezometers should be installed to monitor the watertable to assist in managing the watertable. Depending on the circumstances, there are a number of alternative management options to maintain the watertable above the sulfidic layer.

- In some areas, surface irrigation for example when part of an effluent disposal scheme can help maintain high watertables. In areas with shallower drains, groundwater levels away from the drain will be governed more by evapotranspiration from soil and crops than drain management and hence irrigation can play an important role.
- In some areas, ponding of areas and using the stored water to maintain the water levels once the watertable starts to drop.
- In areas with deep drains, maintenance of levees or dropgates in the drains so the drain level is high will assist in maintaining high water levels in the soil.

When working in acid sulfate soil areas that have previously been drained and exposed to oxygen, it is important to realise that there may be a large reserve of acid stored in the soil. Ponding these areas can release this large reserve of very low pH water. This water if discharged untreated into the environment, can cause very significant acid problems downstream.

5.2 Lowering the watertable

Relief drains are deep narrow drains dug below the watertable and are used to export groundwater that flows into them. Interception drains consists of open ditch type drains or buried pipe system drains usually at the boundary between hill slopes and the estuarine flats which intercepts seepage before it can reach low-lying waterlogged areas.

The inappropriate use of relief or interception drains in acid sulfate soils can lead to rapid lowering of the watertable, poor drain water quality and degradation of the surrounding land.

5.3 Design criteria for subsurface drainage

The design of a subsurface drainage system relies on a number of complex factors and advice should be sought from a drainage consultant. The following issues may need consideration:

a. Hydraulic conductivity and soil permeability

Subsurface drainage systems are dependent upon the soil type, hydraulic conductivity and soil permeability. There are several methods of determining hydraulic conductivity. The simplest methods include well permiameter test and auger hole methods though gulf permiameter or disc permiameter are other useful methods. These methods involve sinking a 100 mm bore hole test to depths below the watertable and either measuring the volume of water added to the hole or removed from the hole to maintain a predetermined water level. The hydraulic conductively is then calculated from this information.
b. **Drain Spacing**

There are several methods of calculating the drain spacing in subsurface drainage all requiring the hydraulic conductivity, soil texture and depth of soil layers to be known. Groundwater usually moves through coarse textured soils quicker than through fine textured soils, so more drains may be needed at closer intervals in finer textured soils. Maintaining the watertable at 0.50 m to 0.60 m below the soil surface will not usually affect production of most crops.

c. **Gradients**

The grade of the subsurface drainage should generally be about 1 in 1000 minimum with grade of 1 in 100 desirable, the velocity when fully flowing should be 0.3 m/s minimum with maximum velocity up to 2 m/s depending on the soil type and drain outlet conditions.

d. **Filters and envelopes**

Filters and envelopes are permeable coarse grained materials placed around the drains (buried pipe drains) to prevent fine grained materials in the surrounding soil from entering the drain and/or to improve flow conditions in the area surrounding the drain and improve bed conditions. A minimum thickness of 75 mm gravel (10-20 mm) around the pipe drain provides an adequate filter and envelope. In some areas geotextile fabrics can be used.

![Figure 5.1 Typical relief drain layouts (from USDA 1973)](image-url)
FLOODGATES

Most farms on low-lying coastal areas will have one or more floodgates. Floodgates are designed to prevent floodwater and / or tidal waters moving on to the farmland and to control the water in the drain which may have originated from upland flows or from groundwater. Most drainage systems on coastal floodplains have several types of floodgates, varying from single gates on small creeks and local drains usually managed by landholders, to large multi-gated systems on rivers, creeks and trunk drains. A flood mitigation authority, drainage unions or the local council usually manages these larger structures.

6.1 System and design
Floodgates are simple structures that prevent water moving within the drain. Most floodgates have a top-hinged flap. The weight of this flap and the pressure of water on the downstream side seal it against a vertical or near vertical mating face. When downstream levels fall, the water head behind the floodgate forces the floodgate open to permit drainage.

Some floodgates can be kept closed when required, to retain water on farmland. However, in this case, the floodgate is often fitted with dropboards that can be manually lifted or lowered by landholders.

The salinity levels in the tidal sections of the coastal waterways will depend on the distance from the ocean and the flow in the river. The lower the salinity, the more options landowners have to open floodgates without salt water affecting their land. Land use also determines the degree to which salinity can be tolerated. Wetland pastures and cattle can tolerate a higher degree of salinity than horticulture or humans.

6.2 Environmental Effects
Floodgates prevent downstream water moving upstream and drain upstream water to the level of the floodgate base. The protection of some low-lying farmlands is a key function of floodgates. However, this manipulation of the drainage system can have a range of impacts on the environment. These include:

- lowering of the watertable
- drying out of wetlands
- changed plant species
- proliferation of weed species
- restriction of fish passage
- reduction in drought-proof pasture refuges
- exposure to air of acid sulfate soils and production of acid
- reduced water quality

6.3 Benefits of modifying the operation of the floodgates
In many cases, by making changes to the operation of floodgates, the detrimental environmental impacts can be minimised. These changes which may be as simple as opening the floodgate at certain times, can lead to improved soil and water quality and increased productivity.
Possible options for change to the operation of the floodgate will depend on local rainfall, salinity, tide levels, and land use and include:

- opening except in times of flood or increased salinity
- temporary opening to flush drains, or to kill weeds growing in drains
- closing after heavy rain to keep fresh water on low-lying farmland, particularly where pasture growth is poor and there is evidence of acid sulfate soils.

There are many potential benefits from opening floodgates during non-flood times and allowing water upstream.

### a. Improved water quality

Flushing in-drain water using the normal tidal cycle can improve water quality. The quality of water behind farm floodgates is often the main reason for opening floodgates. Poor water quality can be due to low flow, lack of oxygen, nutrients, turbidity, or acidity. Crystal clear or milky green water or red iron stains on drain banks may indicate acid conditions.

### b. Reduced exotic drain vegetation

With even minor salt incursions, exotic plant species that have become a problem in drains decline rapidly. Care is needed with the tide levels and amount of water let in or unwanted saline flooding of land may occur.

### c. Enhanced native vegetation

When exotic pasture species intolerant of waterlogging are flooded, they die. The decaying vegetation leads to loss of oxygen from water that in turns leads to fish kills. Introducing tidal water on a regular basis encourages native wetlands pastures that can withstand flooding and provide pasture refuges in times of drought. As a result, the frequency of fish kills may also be reduced.

### d. Increased fish passage

Opening floodgates allows fish and other marine life to move between the main stream and the floodgated section and has potential benefits for the whole area. However, it is important that fish do not become isolated behind the floodgates in potentially toxic low oxygen or high acid conditions.

### e. Improved soil and pasture

In some coastal areas, the lowered watertable have exposed acid sulfate soils to air so that they produce sulfuric acid. This acid affects soil so that pasture growth is poor. In acid sulfate soil areas, consider either

- opening the floodgates to raise the watertable and encourage native pastures species that survive in brackish conditions, or
- use drop boards to ensure that rainfall is contained and does not drain away, keeping the watertable in the adjoining paddocks higher.

### 6.4 Need for a strategic approach

While opening floodgates can benefit on-farm soil and water quality, and pastures, it is not a decision that can be taken by a single landholder. Most coastal floodplains have been drained for decades, and as a result, land in some areas has subsided. If floodgates were opened in an uncontrolled manner, previously dry areas could be inundated.

This means that opening floodgates requires planning and consultation with neighbouring landholders and natural resources authorities. Currently, there is debate about the issue of opening floodgates on NSW coastal floodplains. Landholders should discuss with their neighbours, any
relevant drainage union, council or county council and the NSW Department of Land and Water Conservation whether and how floodgate management should be changed in their area.

Monitoring of salinity and acidity both downstream and upstream will help decide whether to open floodgates. Make regular measurements at the same time in relation to the tidal cycle. Some simple testing is also needed to assess the impacts of any changes to the operation of floodgates. For example, determining how far the saline water will enter the system when the floodgates are opened is vital. The movement of the entering water can be estimated by recording changes in the water height in the drain behind the floodgate during high rain periods. As a next step, the height of intrusion can be measured on an average tidal cycle. However, if water begins to enter areas where it is not desired, the system should be closed down immediately.

Where salinity and acidity are issues, their levels can be measured with simple, hand-held instruments available from scientific suppliers. Regularly recorded visual observations of changes in water quality, vegetation and other physical changes can provide useful information to help modify the operation of the floodgates.

7.
Landforming and improved drainage

7.1 Benefits of improved drainage and landforming

To increase the efficiency of drainage or irrigation schemes, land should be laser levelled to remove isolated depressions and achieve an adequate slope (e.g., a minimum grade of 1 in 1500). During the wet season on the north coast of NSW, excess water has drained very efficiently from vast tracts of levelled pasture, sugar cane, and tea tree country, reducing potential damage to crops and reducing the time before access can be gained to the land. This is particularly important for sugar cane and other crops where earlier access can be gained for harvesting with less compaction caused by machinery.

Prior to replanting any paddocks with crops, it is advisable to review the performance of existing drainage and productivity trends on the land. On pasture country, it may be possible to undertake landforming as part of pasture improvement programs. With semi-permanent crops such as tea tree, it is important that laser levelling is undertaken prior to layout and grading and installation of any infrastructure. To evaluate the most cost-efficient options and plan the works, it is essential that the area be surveyed and both operational and financial constraints be considered when finalising the design.

Landforming requires the services of experts, both to design and undertake the earthworks. This makes it expensive. But a well-designed drainage system will make the land more productive and environmentally sound. Research undertaken in the Red River Valley, Texas U.S.A. has shown that increased crop production is achieved after landforming, and a benefit/cost ratio (a measure of the number of dollars returned for every dollar invested) of up to 1.36 was reached. For example, production increased by 14.3% with soybeans, 18.9% with sugarbeets, and 16.5% with corn following laser levelling.

Figure 7.1 Typical conceptual landforming layout plan
7.2 Steps in undertaking the works

a. First step – a soil survey
To provide adequate information to design the land formation works, a survey should be undertaken on a grid pattern that will vary from 25 to 40 metres, depending on the topography.

If the Acid Sulfate Soil Risk Maps or preliminary soil assessment identify that acid sulfate soils may be present, a detailed soil investigation should be undertaken. Samples holes must be dug with the aid of an earth auger or backhoe pits along drainage lines at 200 metre intervals to a depth of at least 0.5 metres below the projected depth of any drain or land formation cut. Any pit made in ASS may be unstable and it is unsafe for people to climb into such pits. The procedure for the identification of acid sulfate soils is described in the ASS Manual “Assessment Guideline”. In the advent of locating highly sulfidic soils, a finer soil survey 50 metre grid may be needed to locate the extent of these soils. Soil consultants who specialise in acid sulfate soils should be engaged as professional judgement is required in the development of a credible soil investigation and management strategy.

b. Second step – The design
Once the soil investigation has been completed, a conceptual design can be developed. It is important that the final design suits the landowner’s business plan and provides flexibility as well as meeting the objectives for flood, tidal, storm and subsurface water management on the property. The plan should be realistic in terms of likely future returns from increased productivity and the finances of the property owner. In some cases, the works can be staged to meet any budget constraints. It is preferable that all design options are looked at on paper, and their costs and benefits explored at an early stage as it much more expensive to change the design once construction has commenced in the paddock.

The plan should be designed so that the sulfidic layer is not exposed during land forming. Areas where there are existing scalds or the sulfidic layers is less than 0.5 metres below the surface should be treated with extreme care. No drainage or “cutting” should occur in these areas but the use of “fill” over these areas may be an option (depending on the particular circumstances). The professional advice of a soil consultant should be sought.

Where the sulfidic layers are between 0.5 and 2.0 m from the surface, drainage should only be attempted with properly designed drains and treatment of any acidic discharge. Again extreme care should be exercised with any land formation works to ensure that no sulfidic layers are exposed. In areas with sulfidic layers at or below 2.0 m below the surface, drains and land formation of up to a 1.0 metre in depth could be considered. It may be possible to terrace landformed blocks to minimise the depth of cuts, as excessive cuts may lead to loss of production and may risk exposing acid sulfate soils. Normally it is best to adopt a grade to suit the “plane of best fit” and not to exceed 1 in 1200.

Where possible bay lengths should be kept to less than 600 metres, as furrows may over top with longer bays. Sugar cane bay lengths are usually kept between 300 and 400 metres. It is also preferable to design blocks so they contain the same or similar soil types as different soil types have different structure and water infiltration characteristics. In designing the layout, the removal of native vegetation should be avoided and shelterbelts should be maintained wherever possible.

Drains should be designed to be wide and shallow so as not to encounter acid sulfate soils with batters of 1 in 5 or flatter, which will allow the drain to be maintained with a slasher. The layout should include adequate elevated or padded laneways to improve access.
The designer (or contractor) may use one of the many computer-based programs to ascertain the amount of earthworks that may need to be moved. With these programs, it will be possible for the landowner to compare a number of alternative scenarios, before making a decision on a design. In the landforming calculations, the plane is selected so that there is a balance between the volume of cut above the plane and the volume required to fill up to the plane. The density of natural earth changes due to the excavation, cultivation and its moisture content. The final density after compaction compared to the density prior to excavation varies greatly and is difficult to quantify.

The comparison is expressed as the “cut/fill” ration and relates to volumes of natural earth (cut) and the compacted earth (fill). The ultimate soil density is affected by the soil type, organic matter, soil moisture, cultivation history, number of passes and type of machinery used. Calculated volumes can also be affected by the method of computation. The cut/fill ratio can vary from 1.2 to 1.6.

When deciding on the best layout, consideration should be given to
- size of paddocks/blocks/bays
- accessibility during wet and dry weather
- number, location, shape, widths and gradient of drains
- affect on the neighbours
- affect on native vegetation.

The design should be laid out with the preferred orientation and location of an accurate grid survey, with reference pegs, and permanent bench marks for later work. The basic layout options for drains are parallel, herringbone, and double main and random drainage systems. Due to the accuracy needed, the following survey standards should be adopted.
- Vertical accuracy to 3rd order survey to the nearest millimetre on both bench marks and reference pegs, and to the nearest centimetre for other grid levels,
- Horizontal accuracy to +/0.5 metres on bench marks and reference pegs, and +/-1-2 metres on grid levels.
- A grid spacing of between 10 and 40 metres should be used depending on the slope and undulation of the land for example
  - where land is flat with few variations in slope 40 x 40 metres grid
  - where the land is relatively flat and minor undulations 30 x 30 metres grid
  - where the land has significant slope and there are substantial undulations which would not be picked up by a coarser grid 20 x 20 metres grid
  - where the land is undulating and there is need for greater accuracy in calculating the earthworks 10 x 10 metres grid.

Every endeavour should be made to have levels reduced to Australian Height Datum (AHD) and provide at least one bench mark every 40 hectares. All design maps should have sufficient detail for the farmer to interpret finished surface levels, quantities and dimensions.

The design plan should include the following features:
- Bench marks location and features
- North direction
- Scale
- Easement locations
- All topographical features such as fences, lanes, etc that will aide setting out the works
- Reference to natural drainage lines
- Drainage channels locations, slopes, bed elevations and other critical measurements
h) changes in grade need to be shown on the plan
i) changes to top drainage system to be shown on the plan
j) areas that require topsoiling and areas to cut and fill that exceed 80 millimetres
k) cuts and fills at each grid point
l) a design summary detailing the total area, block areas, block slopes, earthwork quantities, the source of earth for channels, lanes and storages

c. Third Step – any approvals
It is wise to check with the local council to determine if any approvals are required for any proposed drainage works. If necessary gain the required approvals.

d. Fourth step – the earth works
Prior to undertaking the earthworks affecting acid sulfate soils, it is recommended that a construction management plan or protocols including a contingency plan be developed to manage the construction and potential impacts in a systematic manner. (See Assessments Section of the ASS Manual).

Landforming should not be undertaken in wet conditions as this leads to the compaction of the soil. To improve the efficiency of land formation, it is recommended that paddocks be prepared well in advance with the removal of vegetative growth.

e. Fifth step – adjusting the drain or farm management plan
At this stage, the implication for the drain or property’s management should be considered and adjustments made to the farm or drain management plans.
Drain Maintenance

NSW has thousands of kilometres of drains in acid sulfate soil (ASS) areas that require regular maintenance and weed clearing. Drain maintenance and weed clearing activities have the potential to cause significant impacts on the water quality in the drain and adjoining creeks and rivers, if the works are not undertaken with due diligence.

Care should also be taken to ensure that maintenance works do not result in the deepening or widening of drains, with the potential to affect groundwater levels and increase the export of acidity. The original drain profile should be maintained or reduced. Any reshaping of drains may require council approval or approvals under other legislation.

8.1 Farm or Drain Management Plan

Acid sulfate soils vary greatly and can present different management problems depending on soil type, drainage design, location, temperature and upstream and downstream factors. It is strongly recommended that those responsible for drains develop a maintenance program as a component of the management plan of the drain.

The maintenance plan should develop protocols for excavator operators or those responsible for:

- removal of weeds and management of any material
- removal of sediment and management of any material
- maintenance of the banks of the drains, any side roads or vegetation
- maintenance of any “in-drain” structures such as floodgates, drop boards or levees
- monitoring of water quality during maintenance works.

For drainage union, county councils or councils, the drain management plan may be a stand-alone plan. For farmers and other property owners, the drain plan may be a component of a whole of property plan that includes crop, native vegetation and groundwater management. In some circumstances, a number of property owners may develop a joint management plan for all the drains in a sub-catchment. Both the sugar cane and tea tree industries are recommending as best practice, that plans of management be prepared for all farms especially those in acid sulfate soil areas.

8.2 The maintenance of floodgates and other structures in the drains

The maintenance of any device affecting the flow of water in the drain is an important component of drain maintenance. In some cases, where floodgates or drop boards are leaking and have not been maintained, consideration should be given to the usefulness of the structure and whether it should be maintained or removed. Any decision made with regard to these structures should be made in consultation with all landowners and relevant councils or government authorities. In some cases, approvals may be required to remove or significantly alter the functioning of the structure especially if it affects SEPP 14 Wetlands.

If a drain is floodgated, the floodgate should be kept closed during maintenance works until all disturbed material has settled. This will prevent turbid sediment flowing from the drain and will enable any acidity in the drain water to be treated with a lime slurry to a recommended pH of 6.5 (see the Management Guidelines in ASS Manual). If a floodgate is not fitted to a drain, other measures may need to be taken to prevent turbidity or acidity reaching waterways. A temporary levee may need to be inserted in the drain while the works are being undertaken.

If the drain dries out (naturally or because of the operation of floodgates or levees), the opportunity should be taken to undertake remediation works. These works could include liming the bed of the
drain, undertake weed control, re-configuring sections of deep drain or fixing and liming eroded banks.

8.3 Sediment removal

If a drain management plan has not been prepared, then before undertaking any sediment removal from a drain, adequate soil samples should be taken from the built up sediment at the base of the drain to calculate the volume and characteristics of the material to be removed. This will allow the operator to estimate the amount of lime or alternative neutralising agent required to neutralise the sediment to be removed from the drain. The soil sampling and analysis should be undertaken in accordance with the ASS Manual.

Sediment removal and drain clearing is best done during dry spells when drains are easier to work. This will reduce the risk of turbid or acidic water inadvertently entering downstream waterways. It is preferable that the drain be isolated from any natural water body during maintenance periods with the floodgate shut or with a temporary levee. If it is necessary to add lime to water in a drain, it is preferable to add agricultural lime in a slurry form. However if hydrated lime is being used extreme care should be taken not to “overshoot” the pH of the water. Cane farmers on the Tweed Valley have developed special machines that can straddle drains to apply lime to farm drains to raise pH levels.

While drains should never be deepened or widened during cleaning operations, sediment built up as a result of erosion of topsoil into the drain may need to be removed. If the sulfidic layer is more than one metre below the drain base it may be safe to dragline the drain to clean the sediment and weeds. However even scraping a little mud each year will tend to deepen the drain over time, exposing the sulfidic material. Generally it is preferable to consider drain maintenance options which do not disturb the drain base.

Any extracted sediment will usually need to be limed, especially if it has been mixed with iron monosulfide material. Iron monosulfide is a very unstable material often associated with decomposing organic matter and fine mud on the bottom of drains. This material has a black oily appearance and may contain hydrogen sulfide, which gives off an unpleasant “rotten egg gas” smell. This material needs to be handled very carefully as it can begin to oxidise and generate sulfuric acid within minutes of exposure to air (as opposed to hours or days for acid sulfate soils material). Some cane farmers remove iron monosulfide from drains and spread a thin layer on a paddock before it hardens. It is immediately limed at recommended rates and ploughed or rotary hoed into the topsoil. Care should be taken to ensure that iron monosulfide are not flushed from recently cleaned drains, as there is a risk that monosulfide can deposit in oysters in any nearby commercial oyster farm and subsequently cause damage to the oysters on exposure at low tide.

Drain clearing operators and equipment

Excavator operators or those responsible for undertaking maintenance, should ask for a drainage plan of management before commencing works on drains in acid sulfate soils areas (as identified in the Acid Sulfate Soils Risk Maps or Planning Maps). Specialised excavator skills are required as the base of the drain is very mobile and almost impossible to “feel” via the controls. Also, the machine buckets operate out of sight almost entirely underwater.

With the high cost of transporting excavators to drain sites, it can be more economical for several farmers to have their drains cleared at the same time. This would allow for joint management of the drain water quality during the period of drain maintenance, and the purchase of bulk quantities of lime for treatment. However, if drain maintenance plans have not previously been prepared, coordinated drain maintenance would only be possible if testing for lime requirements and other management considerations had been undertaken before the excavator is booked.
8.4 Weed removal

The build up of weeds in drains will reduce their efficiency to remove water during flood periods. Modern drains are shallow and broad allowing tractor-drawn slashing equipment to keep the grass or weed under control. However with older-style deep drains, weed maintenance is an ongoing issue. More regular clearing of drains will prevent the build up of plant material and the subsequent settling of iron monosulfide in the base of drains. While regular drain maintenance is expensive, the cost of irregular maintenance may be much higher - the cost of lime treatments associated with larger scale irregular maintenance, dealing with long term accumulation of material and bank erosion and the loss of drainage ability are economic factors to consider.

a. Remove weeds

When removing debris and plant material from drains, care should be taken not to remove the iron monosulfide or “bottom” sediments. There are various approaches including several innovative pieces of equipment specifically designed for efficient plant removal with the minimum disturbance of the sediments. For example, the drainage or reed buckets can be used as a broom to sweep along the drain as well as a scoop across the drain. With this equipment, the tynes which are made of spring steel allow soil, rock and sediment material to be shaken through leaving mostly organic matter for removal. For details about the hire or purchase of Excavator Reed Buckets, please contact the NSW Acid Sulfate Soils Information Officer on 0266 261 344 or email jon.woodworth@agric.nsw.gov.au.

Ideally, all plant material should be removed from the drain and be deposited well back from the bank so that the material does not drain back into the drain. Rotting vegetation from nutrient rich drains will release phosphate and nitrogen. It is better to have this absorbed in nearby soil and taken up in plant growth, rather than running into the drain and promoting further weed growth. If mechanical cutting bars on dredges are being used to remove vegetation in major drains, it is best to undertake these works during times when there is a fresh flow in the drains to remove the floating vegetation.

b. Weeding with chemicals

Some weed maintenance programs may need to combine mechanical and chemical treatments. The use of chemicals can be expensive and is not generally recommended. Their use can lead to rotting vegetation in drains causing low dissolved oxygen levels as well as the chemicals themselves causing environmental damage in the drain or when any water is released from the drain. Many herbicide chemical sprays are not suitable for use in or near watercourses. If chemical spraying of plants is necessary, check with chemical suppliers for details of specialised treatments. Any spray will have to comply with relevant environmental legislation including the Fisheries Management Act.

c. Killing weeds with salt water

In many circumstances weeds can be kept at a manageable level by allowing occasional or permanent intrusion of salt water into drains. If there is a severe weed problem, the rotting of vegetation in the drains can cause low dissolved oxygen levels which can have a detrimental effect on any fish trapped in the drain.

The timing of the intrusion should be carefully planned to ensure damage is not done to adjoining crops. If the drains or land of other landowners are likely to be affected when salt-water intrusion is occurring, consultation must occur before the floodgates are opened. With major drains, NSW Fisheries should also be consulted.
8.5 Management of the drain banks and surrounds

Often the original material that was excavated when digging the drains has remained dumped on the side of the drain where it has oxidised and continues to leach acid even though the works were undertaken many years previously. This material should be limed and preferably capped or removed to reduce acid leaching into the drain (See the ASS Manual for liming rates).

Plants or grass growing on drain banks should not be disturbed as they will help prevent soil erosion on the banks of the drain. If it is proposed to disturb the native vegetation which has recolonised the banks, the provisions of the Threatened Species Conservation Act or Native Vegetation Act may need to be considered.

The maintenance of a gentle slope on drain batters helps to reduce the risk of erosion and the banks collapsing into drains. Where the surrounding land has been laser levelled, levees may need to be redesigned to allow for an efficient movement of runoff from the fields into the existing drains. The levees or drain banks may need to be lowered at selected points. Any drain bank material which is moved or spread over paddocks will need to be laboratory tested and limed at the appropriate rate (see ASS Laboratory Methods and ASS Assessment Guidelines).

8.6 Monitoring

Ongoing testing of water is advised during drain clearing or construction. Monitoring requirements and methods are in the ASS Manual. Large projects may need to use a datalogger to ensure pH levels are stabilised correctly.

References


