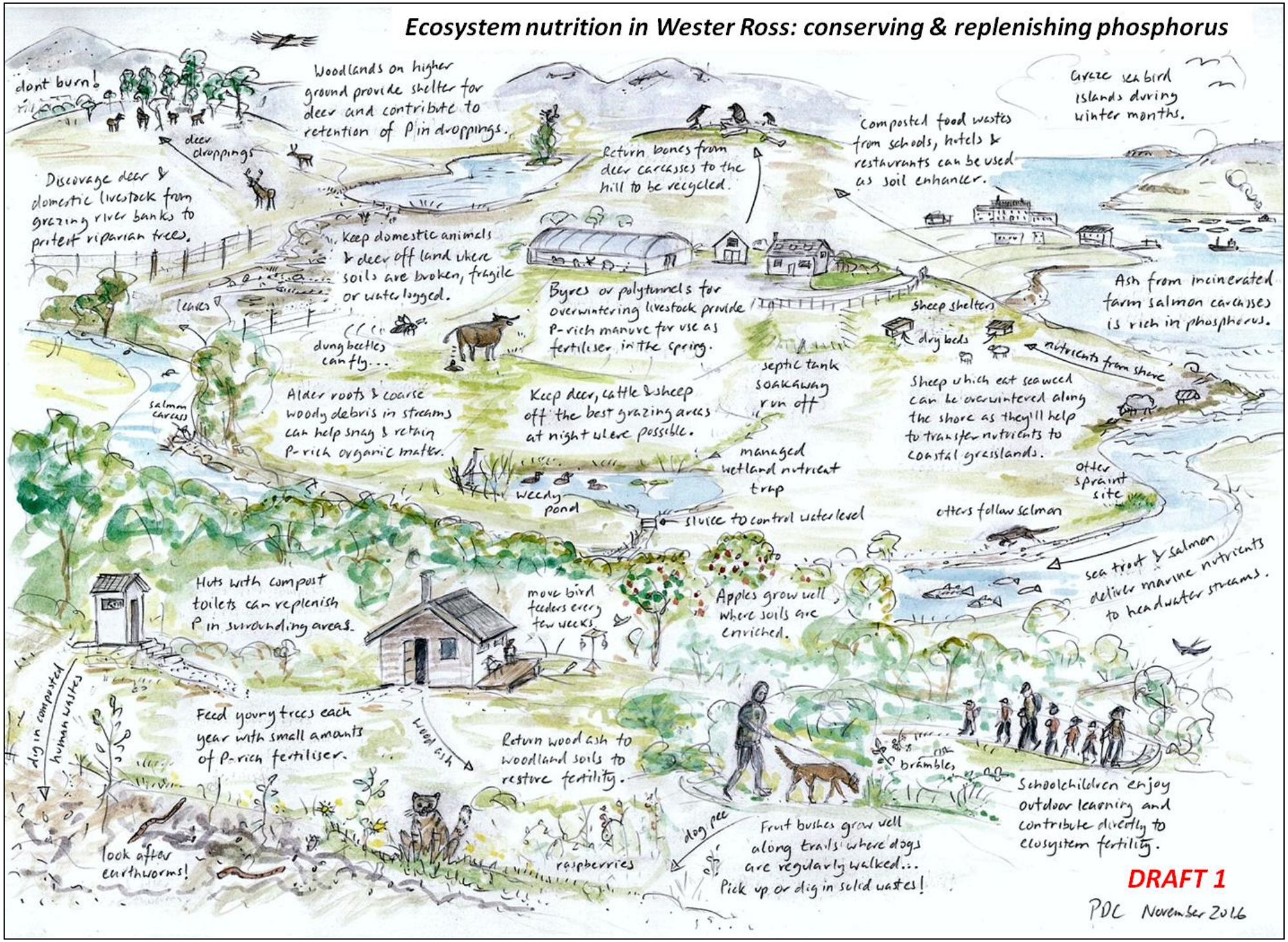
Ecosystem nutrition in Wester Ross: conserving & replenishing phosphorus
dont burn!
deer droppings
Woodlands on higher ground provide shelter for deer and contribute to retention of P in droppings.
Return bones from deer carcasses to the hill to be recycled.
Graze sea bird islands during winter months.
Composted food wastes from schools, hotels & restaurants can be used as soil enhancer.
Discourage deer & domestic livestock from grazing river banks to protect riparian trees.
Keep domestic animals & deer off land where soils are broken, fragile or waterlogged.
Byres or polytunnels for overwintering livestock provide P-rich manure for use as fertiliser in the spring.
Ash from incinerated farm salmon carcasses is rich in phosphorus.
leaves
dung beetles can fly...
sheep shelters
dry beds
nutrients from shore
salmon carcass
Alder roots & coarse woody debris in streams can help snag & retain P-rich organic matter.
Keep deer, cattle & sheep off the best grazing areas at night where possible.
septic tank soakaway run off
Sheep which eat seaweed can be overwintered along the shore as they'll help to transfer nutrients to coastal grasslands.
managed wetland nutrient trap
otter sprainting site
weedy pond
sluice to control water level
otters follow salmon
sea trout & salmon deliver marine nutrients to headwater streams.
Huts with compost toilets can replenish P in surrounding areas.
move bird feeders every few weeks
Apples grow well where soils are enriched.
dig in composted human wastes
Feed young trees each year with small amounts of P-rich fertiliser.
wood ash
Return wood ash to woodland soils to restore fertility.
brambles
Schoolchildren enjoy outdoor learning and contribute directly to ecosystem fertility.
look after earthworms!
dog pee
raspberries
Fruit bushes grow well along trails where dogs are regularly walked... Pick up or dig in solid wastes!
DRAFT 1
PDC November 2016

# Ecosystem nutrition in Wester Ross: conserving and replenishing phosphorus [P]

*Explanation of DRAFT 1, November 2016.* Peter Cunningham info@wrft.org.uk

**'Woodlands on higher ground provide shelter for deer and contribute to P retention in deer droppings.'**

This is partly based on the Swiss National Park studies (e.g. Flueck, 2009) which showed that P is translocated away from grazing areas. The main aim is to address the problem of P moving downhill rather than uphill within Wester Ross. Woodland soils are more likely to be able to retain P than thin wet soils in many open areas. A secondary benefit of deer in woodlands is that in winter trees can provide shelter for deer which would otherwise lose condition faster in exposed locations than sheep and cattle. The difficult challenge is to enable deer to access woodlands during the winter without causing excessive damage to the trees that shelter them.

**'Discourage deer and domestic livestock from grazing river banks to protect riparian trees.'**

This is based on advice provided by many fisheries boards and NGOs to protect salmon and trout spawning streams. In Wester Ross, the Abhainn Gleann na Muice in the upper Gruinard River catchment above Loch na Sealga has riparian alder trees, the roots of which bind the river banks together, protecting riparian soils and providing a fertile green corridor where invertebrate populations (fish food) are higher. However in the upper part of glen the alder trees have been dying off one by one along much of the stream in recent years and not regenerating as a result of grazing pressure by deer. Regarding P retention, if river banks are heavily grazed, trees die and rot, and soil structure is broken; P can be lost through soil erosion as well as lost in runoff of droppings.

**'Keep domestic animals and deer off land where soils are broken, fragile or waterlogged.'**

Over much of Wester Ross, soils are thin and peaty. In many places excessive grazing pressure and trampling has worn the fabric of the soil down to bedrock. If heavy-footed animals continue to be grazed in these fragile areas, especially during periods of wet weather, further P losses occur as a result of further soil erosion and loss of vegetation and the loss of droppings in runoff water. Extreme examples where over 50% of soil has been lost can be seen in several grazing areas, often close to crofting townships. Recovery of P fertility of these areas will require soil restoration initiatives. Techniques similar to those used to quickly revegetate roadsides following construction (e.g. new Glen Docherty road), might work along with deposition of organic matter & ash . . .

**'Keep sheep, deer and cattle off the best grazing areas at night where possible.'**

. . . or I could have said '*control grazing pressure on the best grazing areas*'. Some areas act like magnets for grazing animals as they provide P-richer feed. The main objective is to minimise the loss of P from these areas through leakage associated with over-grazing and thereby maintain fertility, or the need to refertilise as often. By encouraging animals to spend some of the time on higher ground after grazing these areas, there could be a net upward movement of P (to counteract losses associated with runoff and leaching), rather than simply a net downward movement of P out of the ecosystem. This also follows the traditional shepherding practice of removing sheep from the 'greens' in the afternoon, as described in Clark's '200 Years of Sheep Farming in Sutherland'; the old shepherds understood the need to look after the most valuable fertile grazing areas.

**'Dung beetles can fly . . . !'**

In some situations, dung beetles and other invertebrates play an important role in taking dung into the soil. I've watched them along coastal slopes to the west of Gairloch where I'm sure they help to reduce the downward movement of P in the ecosystem and thereby help to retain fertility. If cattle or sheep which have been treated with pesticides to provide resistance against worms or other parasites produce droppings which are toxic to dung beetles, then more P will be lost as the P rich matter is washed away. What are the temperature limits for dung beetle activity; presumably they are less active in the winter – so less able to process deer, sheep and cattle dung?

**‘Return bones of deer carcasses to the hill to be recycled.’**

Bone is the most concentrated form of phosphorus within the Wester Ross ecosystem. Some animals chew bones directly; I’m not sure how much P they are able to reabsorb. Even if some of the bone is not digested, the bone meal in droppings will be more readily available for other biota to utilise. Some estates leave deer carcasses out or put out parts of carcasses to feed wildlife. By returning bones to the ecosystem, much of the P in an animal carcass can be recycled back into the ecosystem, especially if there are animals to chew the bones (badger, fox, deer?) and redistribute bone meal via their dung (c. Newey *et al*, 2016). However consider whether or not there may be health risks associated with this practice if there is nearby habitation or places where people and their dogs may walk.

**‘Composted food wastes from schools, hotels and restaurants can be used as a soil enhancer.’**

There is probably more than enough P coming into Wester Ross to address the phosphorus deficit across large areas; however most of it is taken away again or disposed of in places where it is not needed! In principle, most food wastes including chicken bones and other P rich matter could be made sterile (r. pathogen transfer) through heat-treatment composting. Trials to learn about how such wastes would be absorbed into the ecosystem are needed. These could take place in woodlands or in areas where deer or sheep are grazed following risk assessment. This is in line with much recent scientific literature, including studies in Norway and other countries facing up to the challenge of sustaining supplies of P fertiliser for food production in future years. In some areas, based on comparisons between stunted trees and fertilised trees, rates of biological activity (e.g. grass and tree growth) in W. Ross could be increased by 5 times or more; so potential for production of 5 times as many animals from some areas . . .?

**‘Graze sea bird islands during winter months.’**

This happens already! The main point is to minimise disturbance to nesting birds such as gulls and skuas during the breeding season to let them get on with delivering P from the sea to the land to maximise the amount of P transferred to the island’s soils. If the animals which are grazed following the breeding season are subsequently taken back to the mainland and eaten there, any carcass parts (e.g. bones in chops or legs of lamb . . .) that can be transferred to ground nearby represents a net gain to the ecosystem (see composted food wastes above . . . )!

**‘Ash from incinerated farm salmon carcasses is rich in phosphorus.’**

Large open cage salmon farms around Wester Ross produce many tonnes of ‘morts’ during each production cycle. Both Scottish Sea Farms (at Summer Isles farms) and Marine Harvest (in Loch Torridon) have on-site incinerators to assist with disposal of salmon carcasses. I’ve emailed both companies to ask about what they do with the ash from their on-farm incinerators; responses are awaited . . . Ash from incinerated salmon morts is potentially a huge source of what should be inert (i.e. no pathogens) P-rich fertiliser, comparable in composition to that which is missing from spawning streams, for many uses. Fertilisation trials are required!

**‘Byres or polytunnels for overwintering livestock provide P rich manure for use as a fertiliser in the spring.’**

Animals which are overwintered outside in Wester Ross are colder and wet for much of the time, so have to eat more than those which are kept inside, just to maintain their body temperature. Where there is very limited grazing, and livestock subsist largely by being fed with hay, silage, pelleted feed and supplementary vitamin blocks, keeping them outside will lead to greater P loss as a result of droppings being washed away in rainwater runoff (e.g. along the sides of roads – sheep like to sleep on roads), and/or as a result of soil erosion where animals are fed; so net P loss to ecosystem. Furthermore, trampled grazing areas take longer to recover in the spring; if they have been overgrazed, they will be left increasingly P deficient. So by keeping domestic livestock indoors, P can be retained as manure for use as fertiliser during the growing season. My neighbour kept some sheep in a polytunnel one winter; the sheep were dry and remained relatively healthy; the field below the polytunnel is one of the greenest in the township (and produced a crop of potatoes without much additional fertiliser a couple of years ago).

**‘Sheep which eat seaweed along the shore can be kept outside even during the winter as they’ll transfer P to coastal grasslands.’**

For Shetland sheep which are good at eating seaweed there may be a net gain in P in coastal grasslands, though I’m not quite sure about this? Possibly it depends upon stocking densities. Seaweed is rich in other minerals, though not particularly rich in phosphorus. However, I wonder if sheep also eat the carcasses of dead birds or other stranded dead animals which are richer in phosphorus than seaweed? If they obtain phosphorus from the strandline then leave their droppings in vegetated areas inland, there can be a net gain in P to coastal ecosystems?

**‘Septic tank soakaway runoff; managed wetland nutrient trap . . .’**

The aim is to catch some of the P in domestic waste-water runoff. There are many examples from around the world where this is done in a managed way; systems are being developed to make money from human wastes! I’ve seen examples in Wester Ross where runoff from a septic tank soakaway produces a green grassy flush; places where sheep and cattle like to graze (mostly by accident than by design!). Some septic tanks discharge directly into a nearby water course, sometimes enhancing juvenile fish production (e.g. Kinlochewe waste water treatment works). However overall, discharge into running water represents a bigger waste of P from the system than if the wastewater flowed through a wetland nutrient trap.

**‘Salmon and sea trout transfer marine nutrients to headwater streams; otters follow salmon’**

Studies have shown that even at recent rates of marine survival for Atlantic salmon, there can be a net transfer of P from the ocean to river catchment areas via returning adult salmon (e.g. Nislow, *et al* 2004). What I haven’t seen considered in the Scottish context is the potential for carcasses to be removed from the water by otters (or other animals) and nutrients therein absorbed into riparian ecosystems. The science has been much better studied in NW America where much of the nutrient in some riparian vegetation is derived from the sea via salmon & bears . . .

**‘Roots of alder trees and coarse woody debris can help snag and retain P rich organic matter.’**

This is important in order to maximise production of insect larvae to feed juvenile trout and salmon. There are various studies which explain the importance of woody debris as a source of nutrients for supporting aquatic life.

**‘Don’t burn!’**

From the point of view of retaining fertility in Wester Ross I’ve reached this conclusion after quite a lot of consideration. In principle, burning can help to maintain the quality of grazing areas for sheep or deer by converting P in woody material (e.g. old heather) to ash to be recycled into the soil thereby promoting growth of tender young vegetation. However, based on my experiences and observations of moorburn in practice in Wester Ross over 15+ years, my view is that moorland fires in Wester Ross have done much greater damage to the fertility of grazing areas than any benefit, due to loss of P in smoke, soil damage and loss of P in runoff. Few of the fires that were lit over the past 15 years followed the ‘Muirburn Code’, and many required attendance by fire brigades to extinguish them after burning out of control. Many fires caused long-lasting damage to nearby land. There are extensive areas of fire-denuded ground, particularly on Torridonian sandstone and Lewisian rocks. Recent fires may have led to the biggest net losses of P from large parts of Wester Ross, contributing to the demise of some rural communities.

A quantitative assessment of the impact of recent fires is required to develop a clearer understanding. This should include an overall cost-benefit analyses. It would be useful to find out how many fires achieved their intended benefits, and how many did not, and to estimate how much phosphorus was lost. What lessons could be learned?

However, I accept that in some situation there may be justification for *controlled* burning to safeguard property or for other reasons. Where moorburn is needed, then it should be carried out with far better control than over the past 15 years. A calculation should be made for the amount of P lost in smoke and washed away ash.

Burned ground should be refertilised with P-rich fertiliser to make good the P deficit, or else the outcome will be an increasingly unproductive and barren landscape. P fertiliser should not be applied all at once immediately after the fire, but in small amounts, including after the new vegetation and regrowth has become established . . .

**'Huts [or bothys] with [or without . . .] compost toilets can replenish P in surrounding soils'**

I'm not aware of compost toilets in Wester Ross (though there are some interesting ones in Sutherland?). Examples of bothys in Wester Ross include Sheneval bothy and Larachantivore bothy in the Gruinard river headwaters, with surrounding nutrient-enhanced ground (via use of a spade!). There are several places in Wester Ross where a compost toilet could provide a more appropriate low-cost solution, enabling visitors to make their contribution to ecosystem refertilisation. Compost toilets need to be appropriately designed and managed; there is plenty of literature about how to safely utilise composted human wastes back into the soil to support e.g. tree crops.

**'Return wood ash to woodland soils to restore fertility'**

Tree harvests represent the removal of a large proportion of P within the ecosystem, especially in areas such as much of Wester Ross with thin soils; e.g. harvesting of timber from conifer plantations. To sustain tree growth (e.g. to grow a subsequent crop of trees following clear-fell) and the productivity of woodland ecosystems, the return of wood or biomass fuel ash can help to restore phosphorus and many other minerals and rebuild ecosystem fertility.

**'Feed trees each year with small amounts of P rich fertiliser.'**

The main idea here is that as the ecosystem grows it needs to be adequately nourished, or else growth rates will decline when available nutrients in the soil have been taken up. So it's not so good applying fertiliser on just one occasion and then abandoning young trees (as can be seen in some WGS schemes where many trees have starved then died after 10 years or so . . . ). Not just trees: to rebuild a productive and biodiverse ecosystem where soils have been P-depleted over hundreds of years, regular application (i.e. once every few years for several decades) of P-rich organic fertiliser may be needed to sustain healthy growth

**'Fruit bushes grow well along trails where dogs are regularly walked; pick up solid wastes!'**

I've reached this conclusion after considering the amount of dog urine that ends up in the soil around some of the most popular dog walking areas in Wester Ross! In contrast to sheep, cattle and deer; dogs (and people) normally excrete more phosphorus in their urine than in their faeces. For example, the area around the Laide Community Woodland car park is the most biodiverse and fertile area in the wood, and there are many wildflowers as well as fruit bushes! It's a great place to listen to birdsong at dawn in May . . .

**'Apples grow well where soils are enriched'**

'Watch your feet'! Dogs are frequently exercised in people's gardens where they do their business beneath often very productive apple trees. Another apple grower who I know dug in many trailer loads of wastes from a now long-gone fish and shellfish processing factory in Gairloch; his apple trees produced some remarkable crops. Given adequate fertiliser and shelter, apples trees grow well in Wester Ross. The blackcurrant bushes on my croft are prolific downslope from an old midden (. . . maybe there is a dead sheep or two under there?). Is the same true for hazel bushes and other trees and fruity shrubs?

**'Schoolchildren (and adults) enjoy outdoor learning and contribute directly to ecosystem fertility'**

When I was a child, little did I know that rather than killing the nettles which stung us, peeing on them provided the nutrient enrichment they required to dominate the ground flora in the woods where we played! More pee, more phosphorus: more nettles! There are patches of nettles growing around many old croft houses, and plenty of other green grassy areas where soils have been enriched as people went about their natural business in times past.

*PDC 17 Nov 2016*