APPENDIX 1 – ALTERNATIVES OPTIONS

Early Options

River Almond

Diversion channel

Construction of a diversion channel to avoid the peak river flood flow passing directly through the centre of Almondbank was considered. The peak flow from a storm event would be diverted into a different channel, limiting flow in the main channel to a flow which can be safely passed forward with no flooding.

The potential route that was initially thought possible for flood water diversion is located slightly downstream of Cromwellpark, upstream of the centre of Almondbank leaving from the left hand bank of the river and heading east away from the main river channel to a smaller, un-named water course. This smaller channel flows around the north-east of Almondbank, discharging into the Almond further downstream.

The first problem with this route relates to the topography around the proposed diversion location. The River Almond flows at the bottom of a relatively steep sided valley and as such it would be difficult to transfer the flow from the river into the diversion channel. There is around 10-20m level difference between the two watercourses, illustrated in Figure 1 below. This would be very difficult to overcome and would require very costly engineering works to be undertaken. Some form of retention structure would be needed to sufficiently raise the water level to allow water to gravitate to the diversion channel. This has obvious implications for the natural flow in the River Almond as it would significantly change the existing flow regime.

However, in addition, the increased depth of flow in the Almond would result in flooding at Cromwellpark, just upstream of the diversion point. In fact, in order to overcome this bank height, at least 2km of the upstream valley would need to be flooded to allow sufficient rise in water level to flow by gravity into the diversion channel. At this point, the scheme would have a greater volume of storage than the online storage scheme described below, rendering the diversion channel superfluous.

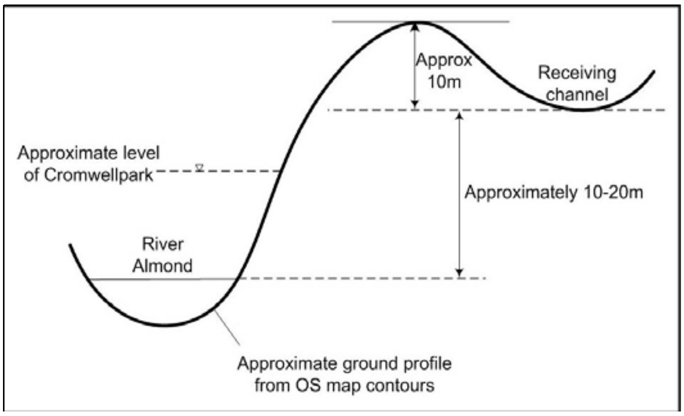

Figure 1: Approximate levels of River Almond and potential diversion channel

This problem could be overcome by constructing a far smaller impoundment scheme than is outlined above, coupled with a pumping station to carry water to the top of the hill. The pumping rate assumed by Mouchel was half of the peak flow rate for the 1 in 200 year return period (calculated as $168m^3/s$). In order to maintain this pumping rate, an area must be set aside to impound water before it is pumped into the channel. This would allow the pumps to operate at a constant rate, despite the variable flow rate in the channel. Whilst the operating head of 20 to 30m is a fairly average operating head for a pump, the flow rate required is extremely high. This would require multiple pumps to be installed along with a large pumping line.

In addition to the difficulties of transferring flow into the diversion channel, the capacity of the receiving watercourse must be sufficient to accommodate the flows. Using the pumping rate suggested above, the diversion channel would need to carry a flow of $168m^3/s$ in addition to the normal flow in the channel in order to prevent flooding in Almondbank. This is an extremely large flow and the receiving watercourse would not be able to carry this magnitude of flow without significant works to improve it. Without these works, the small village of Pitcairngreen would be at risk from flooding and the diverted flow would simply transfer the flooding problems from Almondbank to Pitcairngreen.

In summary, the construction of suitable infrastructure on the River Almond sufficient to allow water to enter the diversion channel, together with use of the channel, fed by pumping or gravity, and its maintenance costs was considered financially unviable. There would also be considerable environmental impacts associated with its construction.

Online storage

Online storage involves the creation of a restriction in the channel forcing flow to back up into a suitable geographical feature. The steep sided valleys of the upper Almond catchment are particularly suitable for online storage schemes, as a relatively narrow, but tall, restriction will result in a large area of retention storage. The aim is to restrict flow to the downstream capacity of the channel, storing any additional flow upstream of the restriction.

To determine the storage required, the capacity of the downstream channel is assessed, the largest flow that can safely be passed forward is allowed to flow down the channel. Any flow in excess of this threshold is retained until the flow drops below this threshold and is slowly released until the river level returns to normal. For a 200 year return period event the peak flow is so much higher than the annual maximum flow in the River Almond, therefore any online storage scheme would need to have a very large capacity in order that flooding downstream can be eliminated.

The online storage scheme would be controlled by a water retaining structure built across the valley floor. This would need to have a penstock or similar flow control device built into it, allowing water to pass freely through the structure at low flows. This would then form a constriction at higher flows, causing water to back up, flooding the valley upstream of the structure, allowing the water downstream to flow in bank along the River Almond.

If the same estimation was taken as above, reducing the 200 year event to the same level as the annual maximum flood level, Figure 2 below shows a simple estimation of the flood storage volume required. Across a period of 2.2 hours, flow would need to be attenuated, holding back a volume of 3,182,400m^3 of water. Making an assumption that the channel is approximately 200m wide when it is flooded, and will have an average depth of 15m, around 800m of the channel will need to be flooded.

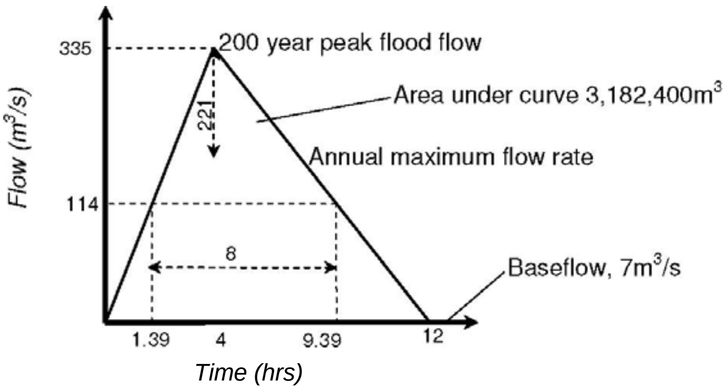

Figure 2: Estimated volume of flood water to be stored on the River Almond

It was considered that the environmental impact of such a large structure could be significant, particularly in light of the high ecological quality of the watercourse. Although, the River Almond is classified under the Water Framework Directive as 'Bad' it does provides a habitat for fish, birds and mammals and is included as part of the River Tay Special Area of Conservation designation. A scheme large enough to protect Almondbank would likely have a significant effect on the quality of the watercourse due firstly to the extent of construction required and secondly to the potential changes to the flow regime up and downstream of the control structure.

In addition, a structure capable of retaining a depth of water in the order of 20m (in order to provide an average depth of 15m), whilst still passing forward a large flow would be very expensive to build. The structure would also require regular maintenance to allow it to operate correctly throughout its life. This would include inspection after every flood event, removal of debris and a walk over of the area used as storage upstream. This could prove relatively onerous, as the effects of smaller storm events would need to be determined to ensure the defence scheme was in a suitable condition to operate effectively during a large storm event.

Since the planned storage volume exceeds 25,000m^3, this storage option would classify the flood management option as a reservoir under the Reservoirs Act (1975). This has further implications in terms of the maintenance and safety precautions which must be taken. Annual inspections must be made and reported by a Reservoirs Act appointed Supervising Engineer in order that maintenance requirements are identified and fulfilled. At less regular intervals a Panel Engineer must inspect the reservoir. Again, this may lead to further maintenance being required. The Reservoirs Act also stipulates that the water retaining structure must have an overflow structure designed to pass the probable maximum flood. This design criteria is necessary due to the proximity of the Almondbank community downstream of the retaining structure.

Offline storage

The topography of the River Almond catchment (steep sided valley) does not present many sites suitable for offline storage schemes. The most obvious sites are at the downstream end of Almondbank, where the valley begins to open out. Unfortunately these sites have either been developed already or are too far downstream to prevent flooding in Almondbank itself. This is due to the influence of Low's Work Weir. Flow backs up from this point triggering flooding upstream, and reducing the flood flow's influence downstream of the weir.

East Pow Burn

Diversion channel

As the East Pow Burn flows into the River Almond through Almondbank, the options for a flood diversion channel are somewhat limited. One option considered was to divert flow around Low's Work Weir and to avoid some of the problems associated with flow backing up in the East Pow Burn. However, the line of Mill Lade (the small channel running off from the River Almond by Low's Work Weir), prevents this from being possible. As no feasible route can be suggested, the possibility of a diversion channel was discounted.

Online storage

The geometry of the East Pow Burn lends itself to small online storage options being employed on the channel. For a large stretch upstream of Almondbank, the burn flows within a sunken valley amongst agricultural land. As such it would be possible to build a small constriction in this area, allowing flow to back up within the channel. Such a scheme on East Pow Burn could be acceptable since the channel appears to have been straightened along some of its reach. As such, there has already been human interference in the flow regime of the channel. However, the effectiveness of such a scheme in preventing flooding in Almondbank was considered. As discussed above, flooding along the channel of the River Almond would not be alleviated by a storage scheme on the East Pow Burn. However consideration was given as to whether flooding at the downstream end of East Pow Burn would be eased by reducing flows in burn with an online storage scheme. If flooding at the downstream end of the burn is as a result of flow backing up due to high levels in the River Almond, then flooding would not be averted even with an upstream storage scheme.

The possibility of an online storage scheme was therefore tested using Royal Haskoning's previous hydraulic model of the burn. This model was built using the U.S. Army Corps of Engineers' hydraulic modelling system, HEC-RAS, using initial data and survey information from Babtie's mathematical model. Simulations were undertaken with a high water level in the River Almond and normal depth at the upstream end of the catchment. The levels chosen represented a 200 year return period flood event in the River Almond, and a minimal flow of 2m^3/s in East Pow Burn. This did not identify any flooding issues at the upstream end of the reach, but did cause flooding at the downstream end, due to inundation from the River Almond. The water level was high enough that the East Pow Burn flow came out of bank on both sides of the channel.

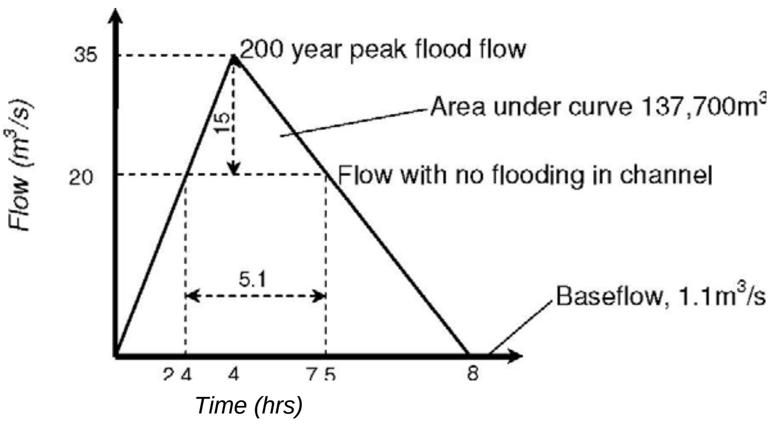

Figure 3: Estimated volume of flood water to be stored on East Pow Burn

Using the hydraulic model, the bank full flow for East Pow Burn was found to be 20m^3/s. This flow rate did not stop the backing up of flow from the confluence with the River Almond, but did prevent flow from leaving the main river channel anywhere else along the reach. From this an approximate volume of required storage was determined. This calculation is shown in Figure 3 and indicates a volume of 137,700m^3 would be required. A site of sufficient size would not be available within Almondbank, particularly within the length of the burn included in the hydraulic model, however a site may be available upstream of the settlement. Here, the ground opens out into farmland used to graze animals with the burn flowing in a sunken channel. An embankment feature, with a suitable flow control structure, could be used here to produce an online storage system. This would cause water to back up, flooding the sunken channel before the water flows out of these banks and floods the surrounding farm land.

Such a scheme would have to be carefully maintained in order that the flow control structure was kept free from debris, without this maintenance, the channel may flood in smaller storms, causing unnecessary flooding to the surrounding farmland. The difficulty in implementing such a scheme would come from the very flat farmland on either side of East Pow Burn. Once the water level in the burn rises above the top of the banks of the sunken channel, it will spread very quickly and shallowly over the surrounding farmland. This would require an embankment to be built around the area of farmland that is allowed to flood in order to prevent water spreading onto land it is not intended to. Without this embankment, it would not be possible to provide sufficient storage volume to alleviate flooding along East Pow Burn within Almondbank. Again, due to the volume of storage required to prevent flooding along East Pow Burn this type of scheme would be classified as a reservoir. This means that that an online storage scheme would be subject to the same maintenance requirements as a reservoir.

As there would still be a requirement to construct a separate flood defence scheme at the downstream end of East Pow Burn, adjacent to the confluence with the River Almond. This type of scheme would have a very high capital construction cost and also high maintenance costs associated because of its classification as a reservoir.

Offline storage

The most obvious location for an offline storage scheme is the agricultural land on the right bank towards the downstream end of the burn. However, this solution would not alleviate flooding upstream of the storage area, furthermore, the areas downstream would still need to flood in order that flow would back up and cause the offline storage to become operational. As such, the practical difficulties of the site outweigh the benefits. The best employment of offline storage would be to couple it with an online storage scheme and flood farmland adjacent to a controlled obstruction. However, as discussed above, due to the flat ground on either side of East Pow Burn, this type of scheme would require the construction of a large embankment to control where the flood waters are allowed to spill. This would render the option financially unviable.

Recent Options Considered by Mouchel

Three solutions were proposed by Mouchel in 2011, based on the results of hydraulic modelling, as follows:

- Solution 1 – flood defence walls and embankments along the River Almond and the East Pow Burn corridors with two storage areas.
- Solution 2 – flood defence walls and embankments along the River Almond and the East Pow Burn corridors with one storage area and a diversion channel.
- Solution 3 – flood defence walls and embankments along the River Almond and the East Pow Burn corridors with one storage area.

Solution 1: 2 flood storage areas and wall and embankment flood defences along the East Pow Burn and the River Almond.

This solution has not been selected as the 'preferred solution' mainly due to the solution incorporating a very large flood storage area which would take a large area of land. In addition, because of its required volume exceeding 25,000m^3 when full, it would come under the Reservoir Act which stipulates that regular inspection over the life of the scheme, incurring possible maintenance costs, would be mandatory. In addition, the storage area would cause a flood risk hazard to the residents of Almondbank in case of a breach / overtopping did occur due to its close proximity to property and infrastructure. Injury to residents (or in the worst case loss of life) is a possibility if failure of an embankment in the storage area did occur when at full capacity.

Note: An additional storage area was also modelled on the field between Deer Park and Craigneuk East and Wes, as part of Solution 1, however it was much more cost effective (additional lengths of walls and embankments would have been needed) not to include this flood storage area. Including this storage area proved not to reduce water levels downstream or added any overall value to the scheme.

Solution 2: 1 flood storage area, 1 diversion channel and wall and embankment flood defences along the East Pow Burn and the River Almond.

For this solution, instead of a storage area located in the Huntingtower field (as in Solution 1) a diversion channel has been incorporated to divert flood water coming from the East Pow Burn to the River Almond further downstream during the 1 in 200 year flood event. This solution would result in reducing some of the flood defence heights along the East Pow Burn compared to Solution 1 due to the reduction of flows in the lower section of the East Pow Burn. Based on the hydraulic modelling, the reduction of defence heights along the East Pow Burn would be no greater than 100mm and the incorporation of a diversion channel at this location would be difficult and costly to implement. This solution has not been selected as the 'preferred solution'.

Solution 3: 1 flood storage area and wall and embankment flood defences along the East Pow Burn and the River Almond.

This solution has been selected as the ‘preferred solution’ as it will enable the town to be fully protected up to a 1 in 200 year return period flood event. An embankment has been incorporated along the lower section of the East Pow Burn in preference to a flood storage area in Huntingtower field or a diversion channel. The preferred solution similarly to Solutions 1 and 2 incorporates a flood storage area in the playing field area and flood defences along the River Almond from the upstream end of the Trout Farm hatchery to downstream of Low’s Work Cottages and the properties at Craigneuk. Flood defences have been also incorporated along most of the East Pow Burn. Defence heights range from approximately 2.5m at the downstream end of the East Pow Burn to less than 0.5m along some of the River Almond reaches.