Storm Water Management in Communities on the Anangu Pitjantjatjara Yankunytjatjara Lands

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Introduction:

The Anangu Pitjantjatjara Yankunytjatjara Lands are located in the far north west of South Australia, adjacent to the Ngaanyatjarra Lands in Western Australia and the Pitjantjatjara Lands in the Northern Territory. They occupy an area of 105,500 sq km and are bounded by the Western Australian and Northern Territory borders, the south Stuart Highway and the southern latitude of 28° 7' S. The rainfall varies from 125 to 200 mm per annum, however these are averages and the range can vary from a few millimeters in drought years to 400 mm in good years. Generally rainfall is unpredictable, because the Anangu Pitjantjatjara Yankunytjatjara Lands are located in a region which is subject to variable weather patterns from the north and south of the continent. These patterns can produce good rainfall in any month of the year.

The intensity of a rainfall event can vary considerably. This variation includes sudden down pours of heavy rain produced by thunderstorms over the summer months to light showers and steady soaking rain during the year. All rainfall events produce storm water in varying amounts which can be beneficial for those living on the Lands as well as causing harmful damage to the environment. Storm water is a precious commodity in Central Australia and programs are required to manage its use.

This article examines the subject of storm water including the nature of catchments, the principles of harvesting and some examples of effective storm water management programs in use on the Anangu Pitjantjatjara Yankunytjatjara Lands.

Natural Catchments:

Storm water is the result of rainfall being collected from a range of catchment areas. It is essential to understand the nature of these catchments and the volume of storm water they are capable of collecting. There are a vast number of catchment areas that collect storm water on the Anangu Pitjantjatjara Yankunytjatjara Lands.

The first type of natural catchment to consider are those contained within the hills and mountain ranges on the Lands. Storm water is collected in the drainage lines, which in turn, feed into the creeks that flow out onto the plains. Some catchment areas are large and produce more storm water than others, causing creeks to flow more regularly. The catchment at Ernabella produces more storm water than the catchment in the hills behind Kalka, resulting in a more frequent flow in the creek at Ernabella than at Kalka. It's important for each community to record rainfall, including the frequency and rate of creek flows. Low lying areas that are subject to flooding, need to be noted so town planners can avoid using these areas in future developments. Creek floodout areas are often ill-defined and difficult to identify and town planners should take care to study the topography which surrounds a community and consider proposed developments in relation to the natural drainage patterns required to manage storm water.

The second type of natural catchment on the Lands are the plains and sand hill country. Storm water collected from the plains, soaks into the soil with the residue collecting in depressions and small creeks. Communities and homelands are built on these plains and contribute to the overall production of storm water. Sites being considered for new communities or for extensions to existing communities, need to be studied carefully before building commences to avoid disappointments resulting from poorly chosen sites. Local knowledge including the patterns of storm water flow in an area should be obtained before pegging building sites and constructing community road systems.

A third type of natural catchment is the micro-catchment and consists of a continuous rock surface which collects and channels storm water into a rockhole or soakage. These are very prevalent on the Anangu Pitjantjatjara Yankunytjatjara Lands and are often referred to as "Tjiwas" (flat rock surfaces). They are scattered across the region and provide a source of fresh drinking water when Pitjantjatjara and Yankunytjatjara people are out on the Lands. Clay pans are another form of natural micro-catchment collection and store storm water for varying periods of time.

Artificial Catchments:

These are usually man made and include the roofs of buildings, roads, compacted areas within the community, airstrips, sports ovals, basket ball courts and the like. They are important because storm water from artificial surfaces usually produce high volumes of storm water, which could be harvested for community use if a management program was functioning. Town planners from city areas where large artificial catchments produce high volumes of storm water, often view it as a product to be disposed of rather than being retained for use within the community. Buildings in communities are often not equipped to harvest valuable storm water, which could be used to irrigate trees and shrubs within the community.

Principles of Storm Water Management:

The most important principle to apply in any storm water management program is to collect and use the storm water produced by the catchment within the locality of the catchment. This is a micro-catchment system, which is opposite to the macro-catchment system operating in the hills and mountain ranges where storm water is collected from a large catchment and channeled into creeks to flow out onto the plains. If storm water is allowed to collect in large volumes within communities, the resultant flow of water will cause environmental damage and the loss of storm water from use within the community. Hence the storm water produced from the roofs of buildings, which are stand alone catchments, should be collected and used in the local area around them. Storm water produced from roofs should be harvested and contained, preventing it from draining into the road systems and collecting into large volumes which become unmanageable.

The second principle applies to the land or plain on which the community and surrounding facilities are located. Large volumes of storm water are often collected from the plains surrounding communities and when channelled into the community road system, cause local flooding, erosion and other environmental damage. The principle is to begin collecting storm water in small amounts from the top of the watershed above the community rather than trying to manage it within or below the community when the volumes of storm water have become too large to control. Measuring the slope of the plain combined with an inspection of the soil surface will indicate the amount of storm water flow that the catchment produces. The installation of a ponding bank system above, within and below the community is usually adequate to contain the storm water produced. In principle, the large macro-catchment which is the plain surrounding the community, is broken up into micro-catchments by constructing ponding banks from the top of the watershed. The topography of communities located in mountain ranges will contain a number of watersheds and associated catchments and each will require a storm water management program.

The road system within the community combined with the compacted areas around buildings and houses is another type of macro-catchment, which has the potential to produce large volumes of storm water. This water should be collected at regular intervals along roads and drained into ponding banks, preventing it from gathering in large volumes and causing environmental damage. In practice, the road system or macro-catchment is broken up into a series of micro-catchments using ponding banks to harvest the storm water produced.

A third principle is the reduction of the uninhibited flow of storm water from compacted land areas around buildings and other areas within the community by changing the flat soil profile to one which begins to collect and absorb storm water. An example of changing the soil profile would be the installation of earth mounds of various sizes, which arrests the flow and absorbs storm water. Grassed areas also restrict the flow and contribute to the absorption of storm water.

The micro-catchment concept ranges from collecting larger amounts of storm water from heavy falls of rain in the larger micro-catchments to collecting small amounts from light falls of rain (5 to 8 mm) in the small micro-catchments. The aim of the system is to collect and direct varying amounts of storm water to special areas eg. at the base of a shade tree. Using these techniques, multiplies the amount of water available from annual rainfall to irrigate each tree. Storm water collected in ponding banks and mounds usually soaks away in a few days and is not a health hazard.

Production of Storm Water at Pipalyatjara:

Pipalyatjara is a small community (270 people) located at the western end of the Anangu Pitjantjatjara Yankunytjatjara Lands on the Amata to Wingellina road about 10 kilometers from the Western Australian border. The community is located around some hills in the middle of a valley between two east west mountain ranges. The land surface on which the community is built, falls away to east and the west with a watershed dividing the flow of storm water. The community has a large number of buildings including a garage complex, a clinic, a large school complex, an office building, store, a women's centre, a police outpost and CDEP shed. The roof areas of these buildings plus those of the 25 to 30 houses, provide a large number of micro-catchment areas for harvesting storm water.

In 2000 the road system in the community was sealed with bitumen providing a macro-catchment system capable of collecting most of the storm water produced from the roofs of buildings and compacted soil surfaces within the town. During periods of heavy rain, the town area resembles the natural catchment model in the hills where the roofs act like rock faces and shed storm water. The road system in turn, acts like a creek and drains valuable storm water out of the community to evaporate on the plains beyond.

For this process to be reversed, the storm water collected by each roof, must be used within the house yard to prevent it from draining away into the road system. Storm water produced from compacted soil surfaces in yards, open areas and around buildings should also be collected and used locally, rather than allowing it to drain into the road system. The bitumen roads should be broken up into micro-catchments by cutting channels through the concrete gutters and draining storm water off at regular intervals to irrigate trees. The task when planning any storm water management program for a small community is to study the macro-catchments that have been created and reduce them to a series of micro-catchments which collect and use storm water locally.

Rainwater tanks have been installed on the houses and help manage storm water. If rainwater is not used and the tanks remain full, then future storm water will flow through the tank, out the overflow and across the house yard and median strip into the bitumen road to be drained away. New programs should be developed to use storm water and prevent its loss from each house yard.

In October 2000, work began on constructing an innovative system of earth mounds as part of the community landscaping program. The first mound systems were constructed in the median strip outside a row of five houses. These mounds were originally designed to reduce the flow of traffic along the median strip thus reducing the hazard to adults and children. As the mounds were being constructed, other uses for them began to emerge.

The mound building program continued until October 2001 and included a range of different designs. It became obvious that the mounds built in yards were able to retain storm water and prevent its loss from the house yard. Mounds built on compacted areas within the community also collected storm water, preventing it from draining into the bitumen road system. Each mound contains many cubic meters of soil, which acts like a sponge soaking up and storing storm water.

Storm Water Management Program at Kalka:

Kalka is also located at the western end of the Anangu Pitjantjatjara Yankunytjatjara Lands north of Pipalyatjatra. It is approximately 15 kilometers by road between the two communities. Kalka has a population of about 90 people and is located on a grass plain, which slopes to the valley floor before slowly rising to the mountain ranges to the north. This community began in 1978, and was home to the Pitjantjatjara Homelands Health Service which provided an effective doctor/sister based service to the area until the Ngaanyatjarra and Nganampa Health Services began in 1983-4.

Initially semi-trailer type caravans were used to accommodate the doctor, nursing sisters and administrative/service staff. Native trees along the dry creek bed, provided shady areas for most of the caravans. Others were located under trees away from the creek, hence the original community was well spaced and joined together by a road system.

As time passed, two transportables were added to the community to house the office and clinic. Permanent buildings began to appear in the early 1980’s, followed by a housing program replacing the caravans. Most of the storm water shed from the roofs of the caravans drained into the creek where it was quickly absorbed by the coarse sand. The building and housing program was located away from the creek on the grass plain which has a slope of 2% and acts like a drain board, shedding storm water quickly and causing wash outs and erosion in the road system. The main road past the community is located along the valley floor and the two access roads into the community act like creeks, collecting storm water from the roofs and compacted areas around the community and channelling it down the slope to the main road.

In October 2000, Kalka people were expressing concern about the damaging effects of storm water to their community. They were unsure about what to do and were discussing the situation with Stephie Rainow (Environmental Health – Nganampa Health Council) and myself. After some discussion, it was decided to bring a laser level with us on our next trip in March 2001 and peg and construct some ponding banks as a beginning to a storm water management program for the community.

In March 2001, it was possible to return to Kalka with some aerial photographs taken in 1987. These pictures clearly demonstrated the floodout areas around the community, thus explaining the reason why some of the houses were experiencing local flooding during heavy rain periods. The topography surrounding the community was simple with the mountain range behind and a major creek flowing through the upper part of the community to a floodout area west of it. A second creek flooded out above the houses on the higher southern side of the main creek.

It was clear that the primary watershed was high in the ranges and the catchment area for the creek through the community was separate from the catchment as defined by the grass plain around the community. The storm water which collected in the ranges, would flow along the creek only when the rainfall was exceptional. The secondary watershed was at the foot of the ranges where the grass plain began. All storm water collected from the top of the grass plain would flow down the slope and into the community road system causing environmental damage. Storm water collected by the roofs of houses and buildings would drain into the road system as well, adding to the storm water problem.

The process of building ponding banks to collect storm water at regular intervals from the top of the watershed was discussed with community leaders. The first part of the program was to collect storm water harvested from the catchment above the community beginning at the top of the watershed. Community leaders took part while a road grader was used to construct the first ponding bank, which was about 50 meters long. They were happy with the result and directed the storm water program to proceed. Their involvement continued during the construction of the 30 plus ponding banks required to manage storm water in their community.

Each ponding bank collects the storm water produced from the catchment above it. Hence they were constructed at close intervals on the catchment above the community, in an attempt to harvest all the storm water produced by each micro-catchment. It was essential that the ponding banks built within the community, would only harvest the storm water produced by the micro-catchments in that locality, rather than having to manage additional storm water, which may flow out of the ponding banks above the community. Road surfaces and roofs of buildings and houses are very efficient at shedding storm water, hence ponding banks were constructed at regular intervals along the roads to drain storm water from them before it collected into large volumes and become a potential hazard.

Ponding banks should be built with one end lower than the other so any excess storm water can flow around the spilling point into the ponding bank below it. The lowest part of the bank should be approximately 100 millimeter below the spilling point and the bank should be approximately 400 mm high. Before ponding banks are constructed, they are surveyed and pegged using a laser level. The length of each bank is determined by the land available for construction as well as the most effective area in which to place the spilling point. A road grader is used to clear the grass from the surface at each side of the pegs. The grader is then used to turn soil in from the topside to make the bank, which creates a pond in the process. The soft soil in the bank is then rolled with the wheels of the grader causing compaction of the soil after the pegs are removed. Grasses and rubbish should not be incorporated in the bank as they would cause weaknesses in the wall and possible breakages in wet weather. The pond behind the bank collects windblown seed, which germinates over time resulting in a natural regeneration of trees and shrubs. Seed collected from local tree and shrub species can also be planted along the bank or in the ponding area. Ponding banks can vary in length from 10 to 50 meters depending on the space available and the slope of the land.

The community at Kalka was established before the ponding banks were constructed, however there was sufficient space available to construct enough banks to manage the estimated amount of storm water, which the micro-catchments would produce. Ponding banks were used to protect the old cemetery from local flooding as well as the office and housing areas. During the period from March to October 2001, after the ponding banks were built the community experienced many falls of rain, which produced large quantities of storm water. A number of home owners commented on the effectiveness of the ponding banks to collect the storm water and eliminate local flooding in their yards.

A new access road into Kalka was constructed and ponding banks installed to collect storm water from it at regular intervals. During the six months after their construction, no signs of erosion were evident along the road even after heavy falls of rain.

The community at Kalka had also become involved in the mound building program which began at Pipalyatjata in October 2000. The area around the office was very compacted and the office roof produced large volumes of storm water, which channelled its way across the hard surface. Community leaders gave clear directions on where to build a mound system around the office. The results were excellent and the many cubic meters of soil used to build the mounds acted as a giant sponge and soaked up the storm water produced by the roof. Mounds were built in other open areas in the community, which have acted in the same way helping to manage storm water.

Management of Storm Water in House Yards:

As mentioned earlier, the roofs of houses and the compacted soil surfaces in house yards act as micro-catchments, producing varying volumes of storm water. Some of the water from the roof is collected in the rainwater tank and is used for drinking and washing. Tank water could also be used as a water supply for air conditioners or for irrigating trees. Storm water from tank overflows often drains away to waste instead of being effectively used around the yard. Tank overflow water should be reticulated to a soakage trench or above ground facility where it can be used to irrigate fruit trees. The volumes of storm water produced from tank overflows on the Anangu Pitjantjatjara Yankunytjatjara Lands is usually sufficient to support a number of fruit trees in each house yard.

If the compacted soil surface in a house yard is flat or slopes away, it needs to be modified to collect and retain storm water to irrigate trees and shrubs and possibly some lawn within the yard. The construction of earth mounds in house yards has provided a solution by altering the shape of the surface around houses at Pipalytjara and Kalka on the Anangu Pitjantjatjara Yankunytjatjara Lands. The mound systems installed, consist of a number of smaller secondary mounds surrounded by a primary mound which acts as a peripheral retaining wall. These mound systems have been effectively harvesting storm water since their construction. Excess storm water from roofs, spill over into the front yard and is collected within the mound system. Many residents have commented about the excellent growth of established trees after mounds have been built around them.

Mulberry trees planted many years ago in house yards at Pipalyatjara and Kalka are receiving sufficient storm water to produce growth and fruit each year. Their root systems are extensive, making it possible for them to obtain ground moisture from stored storm water under the house foundations and in other parts of the yard. Each community should be encouraged to landscape house yards with designs, which collect storm water to irrigate fruit trees suitable to the area.

Wherever possible, rainwater tanks should be located at the rear of the house so the overflow can direct storm water into the back yard or side yards of the house. The house yard should be landscaped with a combination of mounds in association with the septic tank and soakage trench and other soakage areas for storm water. A combination of shade, shelter and fruit trees should be planted to create a micro environment around the house, which is sustainable on the long term. Initially the trees would require irrigation during the early years of establishment. It is essential to build this micro environment to reduce the internal temperature of the house as well as include outside living areas, which are very much in demand on the Anangu Pitjantjatjara Yankunytjatjara Lands.

Management of Storm Water in Community Areas:

Community areas are often large, compacted areas providing suitable surfaces for collecting and draining storm water into the community road system. This process should be reversed and storm water retained for local use. Because of the openness of these areas, there is usually sufficient space to install earth mound systems in patterns, which allow public use of the areas as well as the collection of storm water for irrigating shade trees. Several of these areas at Pipalyatjara and Kalka have had mounds constructed on them, usually around existing trees and the results have been excellent. The storm water produced off each site is now being used more efficiently, rather than flowing across the site causing erosion to the surface and rendering it of less use to the community.

Anangu appreciate openness around their communities so they can communicate with others over reasonable distances. Sign language is commonly used among Anangu and people need to be seen before it can be used. Hence landscaping designs should include an openness for people to communicate. Rearranging open flat compacted areas with mound systems doesn't interfere with the above need but rather enhances it. Anangu are now sitting on mounds and taking advantage of the elevation they provide, thus increasing their ability to be watchful within their community.

Storm Water Management and Town Planning:

Over the years, there have been many different town plans drafted for communities and homelands on the Anangu Pitjantjatjara Yankunytjatjara Lands. It's often not easy to incorporate all the parameters one would like in a town plan, however experience has shown that certain features should be included. The effective management of storm water in communities require the following.

1. Size of House Yard. Experience has shown that the size of house yards used in the past, has been too small and the storm water they produce, flow out of the yard and across the median strips into the road system. House yards need to be approximately 50 x 50 meters in size if they are to collect and use the storm water they produce. The front yard should have a depth of 15 to 20 meters to allow for mound building and the back yard should be 10 to 15 meters deep. These dimensions will vary according to the direction in which the house yard slopes.

2. Median Strips. These are usually the strips between the house yard and the road system. The width of median strips will depend on the size of the house yard and will vary between 5 and 15 meters. The width will also vary according to the frequency of traffic using the road. Median strips can produce large volumes of storm water and sufficient space should be allowed for the construction of mound systems to manage it and reduce the amount, which would normally flow into the road system.

3. Road Systems. Initially communities are designed with a dirt road system and the width of roads should be approximately 10 meters. Road widths are usually determined when median strips are being designed. Because road surfaces become very compacted, they are capable of producing high volumes of storm water, which if left to flow unchecked, will cause erosion and loss of soil. Hence road systems should be designed on the contour where possible to avoid excessive slopes along their length. Some roads will be built down the slope and in these cases, sufficient land should be set aside for harvesting storm water from them at regular intervals. All roads within the system will produce storm water and sufficient land should be set aside to harvest it.

4. Community Buildings. These include the local store, the office, the clinic, the garage, the school complex and other buildings. The roofs of these structures will produce sizeable quantities of storm water which should be managed. Hence, sufficient land should be set aside to collect and use this water. Often storm water from these buildings is not stored in rainwater tanks and communities should be encouraged to install large capacity tanks for this purpose. When designing community buildings, sufficient land should be set aside to include a landscape around the building, which has the capacity to collect and use the storm water produced from the roof and the surrounding yard.

5. Natural Catchments, Creeks and Floodouts. It is essential to study the local topography of an area when a community or homeland is being planned. The Anangu Pitjantjatjara Yankunytjatjara Lands are a combination of mountain ranges, hills, undulating plains, sand hills, swamp land and clay pans. It is inevitable, that wherever a site is chosen to build a community, natural storm water drainage systems will be operating. These systems should be mapped and the town plan integrated with them.

Care should be taken when planning creek crossings in communities. If they are badly constructed, the storm water they carry, may flood out into the town causing much damage. In some cases, communities are isolated by major creeks and town planners should draw on the knowledge already available to construct appropriate crossings. Local knowledge should be sort out at all times in respect to the behavior of storm water within the locality. Many failures in town plans are due to insufficient consultation and consideration of local knowledge.

6. Sports Ovals, Basket Ball Courts etc. When sports ovals are being planned for communities, they need to be located in areas, which are able to manage large volumes of traffic. There is usually a ring road around the oval, which has the capacity to collect storm water. The road should be designed and constructed to collect and direct storm water into areas where shade trees have been planted around the oval. It is often desirable to construct a continuous low mound around the oval for spectators, which would also serve as part of a collection system for storm water. When constructed, ovals are usually large open earth surfaces, which have the capacity to collect storm water. Because the surface is partially compacted by people's feet, it retains a porosity to absorb storm water. However, care should be taken to choose an oval site, which is reasonably flat allowing storm water to soak into the surface, rather than collect and flow across it.

Basket ball courts are often built in locations without any thought of planning a system, to harvest the storm water they produce. If the court is to be surfaced with concrete, care should be taken to drain the storm water off for use on shade trees around the court. Some courts are surfaced with pavers allowing storm water to soak into the joints between them. Any artificial surface that has the capacity to shed storm water, should be part of a system that can use the water it collects.

The Future of Storm Water Management:

Storm water is a free resource available to people living on the Anangu Pitjantjatjara Yankunytjatjara Lands. It mostly flows off roofs, across open areas of land and along roads, etching out gutters, eroding the road surface and depositing large volumes of soft sand in its wake. For most people living on the Lands, storm water is regarded as a problem because of the lack of programs to manage it. As management practices are developed, this situation will change and storm water will be better utilized.

The roads program across the Lands is a good example of improving management practices. Over the years, many of the main roads have been upgraded, so the road surface sheds storm water into long drains, which in turn irrigate the local vegetation. Roads are now passable in wet weather and the storm water they produce is no longer a problem. This indicates a change toward better management of storm water.

The next step is to introduce beneficial storm water management practices into our town plans. The use of land for roads in communities needs to be re-assessed. The spatial arrangement of buildings in relationship to topography should be planned to include practices for better storm water management. Vacant land needs to be set aside for the collection and use of storm water. Micro environments need to be developed around houses and should include the use of storm water for plant growth associated with outside living areas.

Every attempt should be made to reduce the amount of ground water used by a community each day. Storm water is a good alternative for supplementing the ground water supply on the Anangu Pitjantjatjara Yankunytjatjara Lands. Town planners, community planners, road builders, engineers and others should complement their work with effective storm water management systems, thus improving the quality of life in communities across the Lands.

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The aerial photographs of Pipalyatjara and Kalka were courtesy of David Franklin from Pitjantjatjara Council Projects.

Storm Water Photographs - Pipalyatjara

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1. View from the east of the Pipalyatjara community which surrounds a small hill in a valley between two mountain ranges [May 2001].

2. Storm water harvesting programs are required to prevent storm water from roofs, flowing across open areas and into the road system [October 2000].

3. Storm water is a precious resource which should be drained off roads at regular intervals to irrigate trees and shrubs [October 2000].

4. Storm water collected from the yard and roof of this house has provided the irrigation water necessary to support growth and fruit production from this mulberry tree [June 2001].

Storm Water Photographs - Pipalyatjara

5. This mound system was built in the front yard of a house at Pipalyatjara. It was constructed around two mature pepper corn trees and collects storm water from the roof and yard [June 2001].

6. Mounds like this one were built in open areas around the community to collect storm water, thus preventing it from draining into the road system [May 2001].

Storm Water Photographs - Kalka

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1. View from the south of the Kalka community. The creeks which drain out above the community and flow through it are visible in the foreground [May 2001].

2. View from the north of the Kalka community with the new access road and the ponding banks visible in the foreground [May 2001].

3. View of the ponding banks built from the top of the watershed to manage storm water, preventing it from entering the community road system [March 2001].

4. View of ponding banks in the centre of the photograph which collect and divert storm water from the creek floodout above the houses [March

Storm Water Photographs - Kalka

5. View of ponding bank construction at Kalka. The grass has been cleared away and soil is being turned in from the top side to form the bank [March 2001].

6. This ponding bank was designed to collect and drain storm water from the main internal road system to an open area outside the community [March 2001].

7. The wheels of the road grader are used to roll and compact the bank during construction [March 2001].

8. View of the ponding bank built above the office area to collect and drain storm water, preventing it from causing local flooding and erosion [March 2001].

Storm Water Photographs - Kalka

9. The storm water collected in this ponding bank, no longer floods through the house yard below it [October 2001].

10. Storm Water collected in this ponding bank can be used to irrigate trees rather than drain away through the internal road system [October 2001].

11. Storm water run-off from the main access road is collected in ponding banks at regular intervals along the road [October 2001].

12. Mound systems are being built on open compacted areas to change the shape of the soil surface and collect storm water, thus preventing it from draining into the road system [October 2001].

Storm Water Photographs - Kalka

13. Storm water collects on open compacted areas around communities and if left unchecked, begins to flow and cause erosion [October 2001].

14. Storm Water from the roofs of houses should be collected and used in the yard before it escapes and erodes channels like these across open areas as it flows toward the road system [March 2001].