Sustainable Architecture
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Lecture – 24
Sustainable Sites - IV

Welcome back to this new lecture for the online ongoing course on Sustainable Architecture, and we have been discussing about the Sustainable Sites and how to design and develop them. So, this is the 4th lecture in the series where we have been discussing about the sustainable sites.

In the previous one, we have talked about the selection of sites, the development, then we also talked about the design of these sites to mitigate the urban heat island impact. And in today's lecture we will be talking about the management of stormwater and reducing the runoff from the developed sites.

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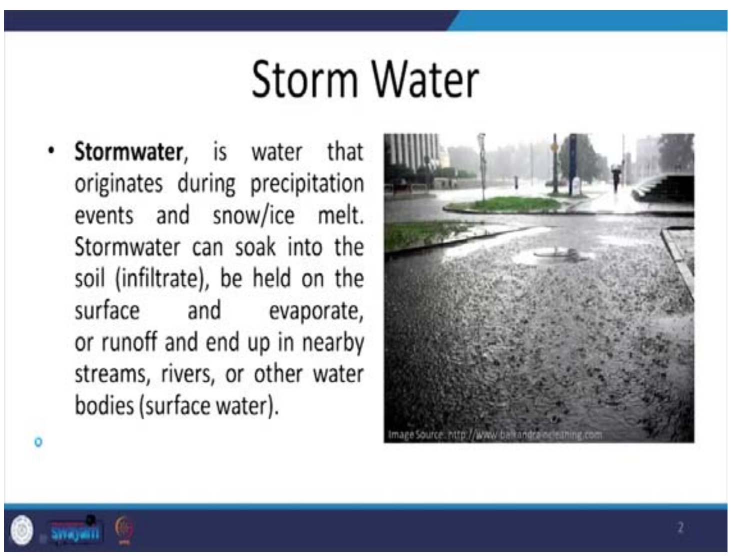

So, to start with, what is stormwater? Stormwater is the water that actually originates during precipitation. So, whenever there is rain or there is snowfall or the ice melts so that is when these storm water comes in. And we have been seeing around us that more and more cities are actually getting flooded during the monsoons. So, unfortunately when rains used to be the time which everybody would enjoy and welcome, our cities and the people in cities are actually not enjoying rains.

Simply because the rains and the stormwater which is a resultant of these rains that is not well managed. It is not a problem, but it is a problem when it is not managed well. And that is more pronounced in our cities because we have more and more of hard surfaces. Let us see what are the components when we talking about these stormwater management and what all are the parameters which go into consideration.

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But before that if we properly manage our stormwater, it brings about a lot of benefits to us. So, we have proper drainage of surface runoff. Whatever runoff actually happens we can see a lot of draft, but we can see that there is not much of accumulation of stormwater anywhere else because these it has been well managed. So, there is ample volume, sufficient volume of the drain to take care of the stormwater.

So, there is proper drainage, it does not create problems for the day-to-day life in cities, urban areas largely. Then this collected water can actually be used for groundwater recharge or urban landscape or farming for other purposes. So, it can be further reused. While in other cases it will actually go unused.

Then we can treat the water in very early stages. Now, here if it is not properly managed, it may actually the stormwater which is good water can actually merge with the grey water or black water in the drains and that cannot be treated or if it has to be treated then it will come at a very high cost, at a price which is much more than if we intercept if we collect the stormwater early and then treat it.

The next benefit is it avoids damage of infrastructure. For example, the streets, the buildings, private properties or public properties. So, if there is storm water which is what we see that the low lying areas of the cities actually get flooded because the storm water was not managed and the public property actually gets damaged which is what we can avoid. And that is a substantial cost, it adds a lot to the economic cost.

And this stormwater if properly managed can be integrated into urban landscape and it can help provide for the green and recreational areas. So, some of the sustainable cities, I am not talking about just a neighborhood level or a small building site level, but at a city level people have created green parks in such a manner that those parks serve as ponds during the monsoons during the rains and by the time it is summers all that water has percolated down and it allows green areas for people to use during the summers and springs. So, stormwater management actually provides us a lot of benefits.

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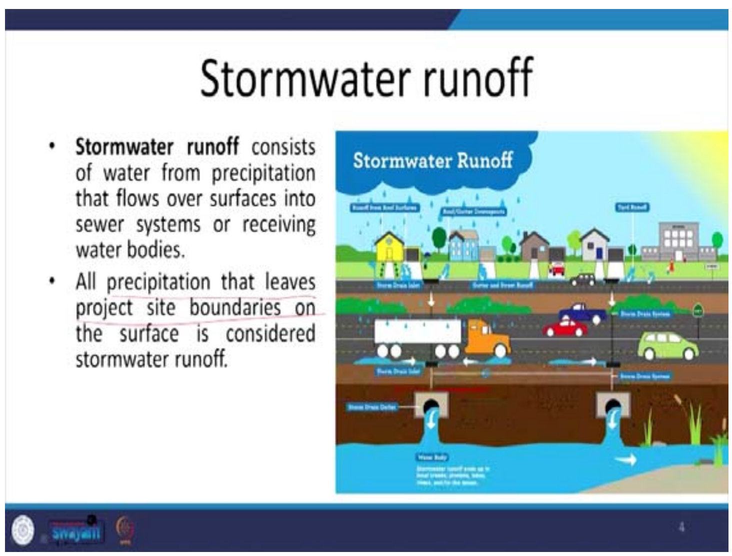

Now, when we are talking about stormwater runoff, we are talking about essentially the water which is generated which is there because of precipitation, rains and that actually flows into the drains. Now, these drains have to be separate drains for sewer systems and for stormwater, but unfortunately in cities both these drains are often combined. So, the same drains would carry the storm waters as well as the grey water or the black water. And then all these drains are opening into the water bodies, hopefully after infiltrations, after treatments. So, we are talking about the stormwater runoff as the precipitation that leaves the project site boundaries and it is getting collected through the drains and in a properly organized manner that is what the stormwater runoff is.

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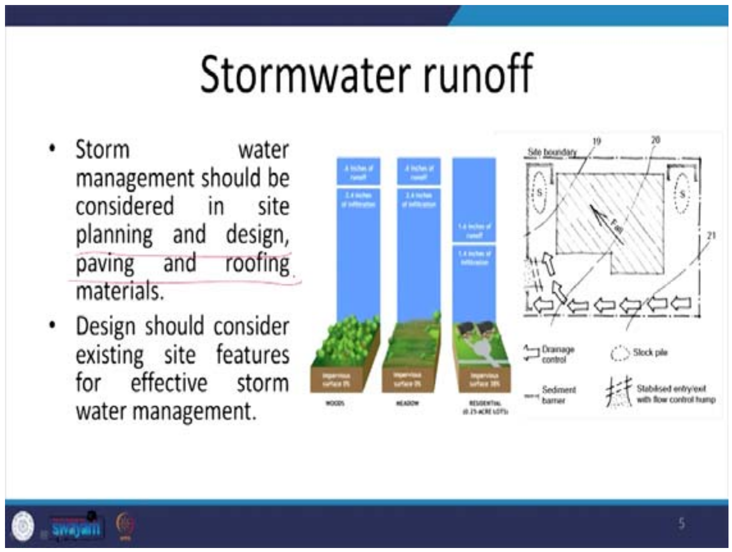

Now, when we are talking about the stormwater runoff, we are talking about the planning and design of the site, we are talking about the kind of materials which are going to be used. So, largely two components where we talking about the design and planning aspect of it and we are talking about the right selection of materials.

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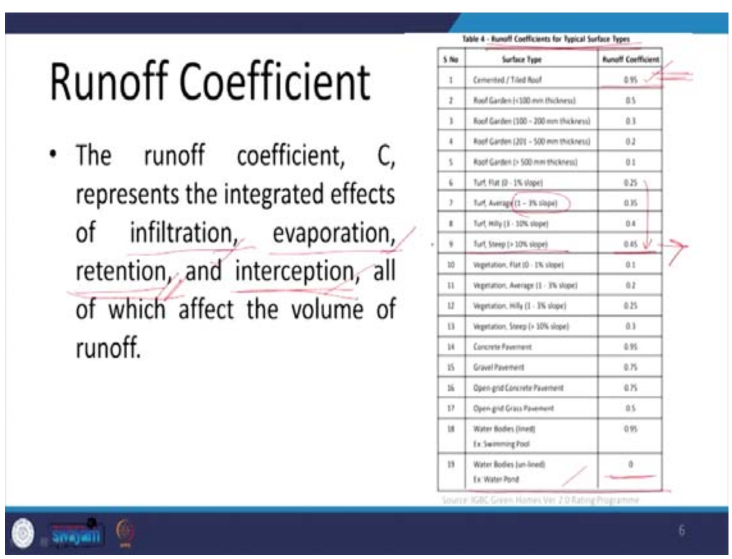

S No	Surface Type	Runoff Coefficient
1	Cemented / Tiled Roof	0.95
2	Roof Garden (<100 mm thickness)	0.5
3	Roof Garden (100 - 200 mm thickness)	0.3
4	Roof Garden (201 - 500 mm thickness)	0.2
5	Roof Garden (> 500 mm thickness)	0.1
6	Turf, Flat (0 - 1% slope)	0.25
7	Turf, Average (1 – 3% slope)	0.35
8	Turf, Hilly (3 - 10% slope)	0.4
9	Turf, Steep (> 10% slope)	0.45
10	Vegetation, Flat (0 - 1% slope)	0.1
11	Vegetation, Average (1 - 3% slope)	0.2
12	Vegetation, Hilly (1 - 3% slope)	0.25
13	Vegetation, Steep (> 10% slope)	0.3
14	Concrete Pavement	0.95
15	Gravel Pavement	0.75
16	Open grid Concrete Pavement	0.75
17	Open grid Grass Pavement	0.5
18	Water Bodies (lined) Ex: Swimming Pool	0.95
19	Water Bodies (un-lined) Ex: Water Pond	0

Source: IGBC Green Homes Ver 2.0 Rating Programme

When we talking about the materials, we are concerned about the property of these materials which is called as runoff coefficient. Now, this table gives the typical runoff coefficients for these different types of surfaces, different types of surface type options.

Now, the higher runoff coefficient implies that most of the water which will be available which will be there during the precipitation through the precipitation will be running off and there will be very little which will be either infiltrated to the ground or evaporated or retained or intercepted.

Now, here when we are looking at only the surface property, we are largely concerned about how infiltration and evaporation happens retention and interception is by virtue of the design. So, how the material is used on the site, how, what are the different levels, how the flow is going to be intercepted, whether there is a pond, whether there is a water body for attention or not. So, these two are largely taken care of by virtue of design and here we are talking about the different surface types.

Now, here if you see we are also talking about the slopes. So, we are talking about the retention capacity. The steep the slope is higher is the runoff coefficient. So, if we have a turf which is steep, so we can see that it increases from a flat turf to a steep turf and there runoff increases which is commonly seen and understood phenomena as well. But we know that around 45 of the water the precipitation will we will actually runoff.

If you look at the water bodies which are unlined for example, water ponds which are naturally present because of the topography and being there we see that the runoff coefficient is 0. So, there is no water which will actually be running off from this water body. So, a lot of infiltration will take place infiltration to the ground, there will be some evaporation and it is retaining most of it and it is also intercepting it before it flows out. So, there is a runoff coefficient of 0 which is the ideal case ideal scenario.

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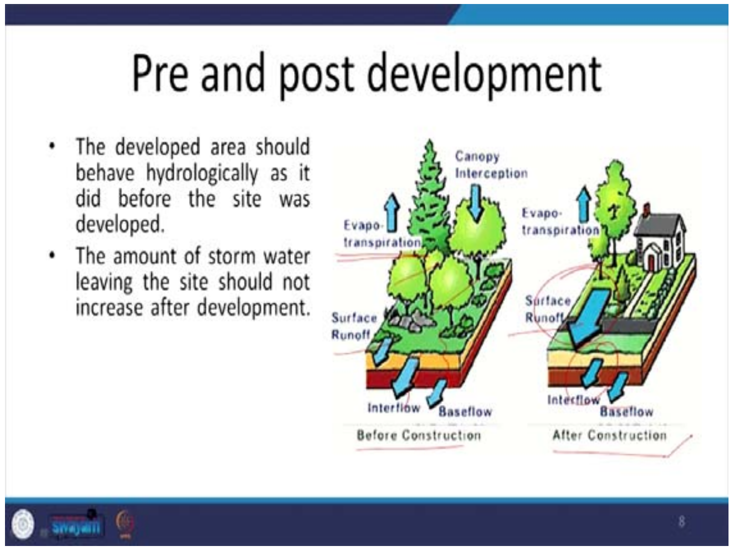

So, when we are designing a site, we are looking at the pre and post development scenarios. What we have to try doing is we have to have the same amount of runoff even after the development as it was before the development and construction had taken place. So, if this was the undeveloped site and there was a lot of vegetation, so there were there was water which was going towards evapotranspiration and then there was surface runoff, there was interflow which was right beneath the surface and then there was base flow where the water was actually percolating to the ground. However, if we look at the after construction scenario we see that the volume of surface runoff has substantially increased because the vegetation is not there as much.

So, the surface type allows more water to be runoff and there is less which is there in the base flow and largely inter flow. So, this is not a good scenario. More surface runoff implies more water which can actually be percolated to the ground and can be used is being run off to the drains in urban areas we are saying. So, it will largely be running off to the drains and become water which is non-usable or which requires treatments before it can actually become usable.

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So, we are talking about imperviousness. Now, imperviousness as it is literary meaning also indicates is the capability of a surface to allow water to permeate through it to the lower surfaces. That is what imperviousness of a surface would be.

Now, when we are looking at a site development, we should promote that the run off and the perverseness of the surfaces is less than 50 percent, so that more and more water is allowed to stay on the side and percolate down to the ground and not runoff to the drains.

We are talking about the capability of a material to allow percolation of the stormwater to the lower strata of the ground, the reverse of which is imperviousness. So, we want more and more surfaces to be pervious. We want less than 50 percent of the site to have higher perviousness or for perviousness of more than 50 percent and this will promote more and more water to be retained on the site and not run off from the site going into the drains.

So, if we look at the intent which we have just talked about, we want to retain the pre development hydrology and allow less and less of surface runoff and the water to reach the surface aquifers through the drains or otherwise.

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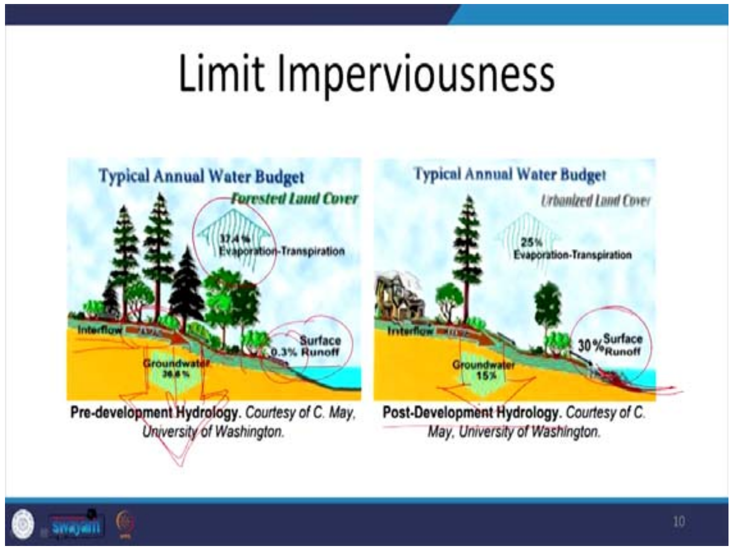

So, in case of a predevelopment scenario where a lot of built surfaces, lot of hard surfaces, impervious surfaces were not added we would see that a lot of groundwater recharge was happening naturally.

So, in this case we see that there is a lot of ground water recharge there is a lot of interflow which is right beneath the topsoil, that is because of the presence of these the roots of the trees which make this top soil and of the top layer of the soil more permeable, so that there is more recharge and there is greater interflow and there is a greater evapotranspiration happening. So, the total amount of runoff to the surface aquifer was only 0.3 percent as compared to a post development scenario where we see that almost 30 percent of the surface runoff is received in the surface aquifers.

Now, if this was the case where the urban area whatever city is being developed had the possibility of or the proximity of these surface aquifers and that the surface aquifers had enough capacity to hold all that surface runoff, that would still be a manageable scenario where we have most examples of cities where we do not run off to larger water bodies we have even eaten up, taken up these water bodies. So, where does this water go? It actually enters our homes. And since there is less and less of groundwater recharge percolation to the ground, there is less and less of groundwater available. The ground water table is further going down.

So, earlier where we would have groundwater at around 35 feet, 40 feet, now we have groundwater table which has gone down to 150, even 200 feet we cannot find water that is what the effect of this increase runoff is. And for those same reasons we have to limit the imperviousness and also the runoff from our developed sites.

So, the kind of strategies that we are looking at when we are talking about increasing the perviousness and reducing the runoff, so these are some of the strategies which is commonly used, which are commonly implemented when we are talking about development of site for reducing the runoff.

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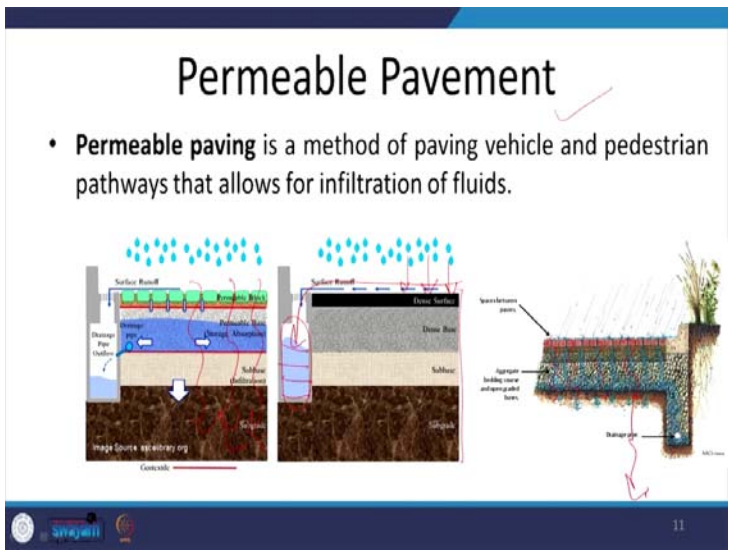

So, first is permeable pavement. So, we are talking about a pavement which allows percolation of water through it and into the ground. We are, unfortunately most of the materials which we use these days are so dense that they allow 0 permeability, there is no percolation of rainwater and all of it goes into the drains thereby we require more drain size, greater wall to hold greater volume of the stormwater, unlike a permeable pavement where this will allow not 100 percent of it, it will not still not be comparable to a vegetated green surface, but it would still be better. So, we are looking at pavements which are permeable.

Now, this is a very good strategy for our streets for our roads which have to be lined which have to be paved. But we can have permeable pavements there where there will be more percolation to the ground.

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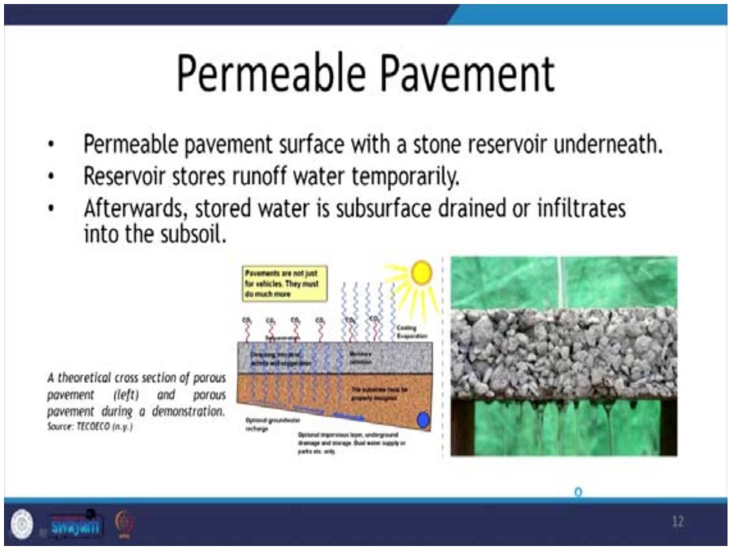

A lot of research is actually happening when we are talking about the permeable pavement, so that our streets our pavements on roads actually allow for groundwater percolation.

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So, there are permeable pavers, there are permeable concretes, we also have grass pavers which is a very common strategy where we actually see that the paver is having punctures and the vegetated area it. So, it allows for growth of grass and that also allows for percolation of water down to the ground.

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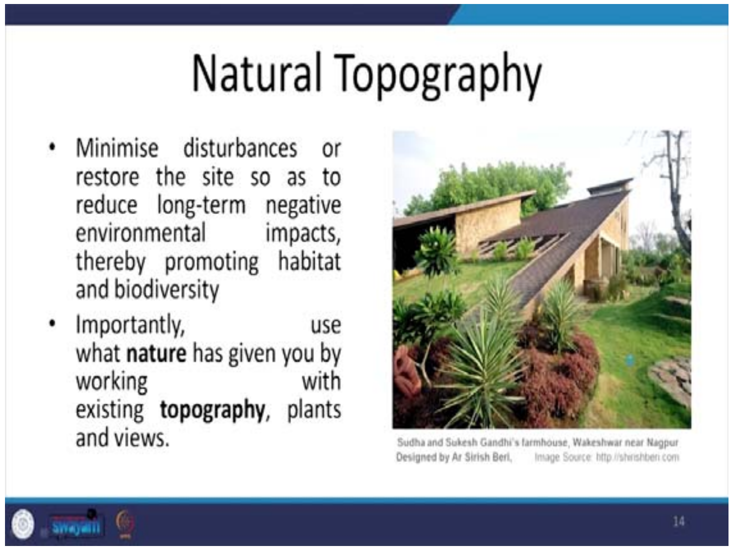

Another strategy which is a design strategy. So, this is a mix of strategies we are talking about materials and we are talking about design which are the two aspects here when we are talking about stormwater and its management.

So, the second major strategy which is a design strategy is to maintain the natural topography. Now, this is at the building level, a micro scale of development to a very large level which is a city development we have to respect and retain the natural topography which is unfortunately not happening. Earlier all the low lying areas in the cities were actually used as surface aquifers, water bodies, that is why we see in majority of the villages even when we go today the ponds are actually the low lying areas.

So, naturally all the water is going to go and get retained there. So, with the help of creation of a small bund or a small boundary around the pond or the low lying area it will be able to hold all the water which will come running to it and since it is not lined, the bottom of it will not be lined, so it will allow percolation.

Now, the design feature here was besides the engineering of not lining it or adding a bund to it or adding a boundary to it, the main point was topography and selection of such sites which will actually receive a lot of water. Now, if you look at newspapers days, in during the monsoons you would find the newspapers flooded with the news of every city I am saying that this area got flooded, so there is water in the homes people had to be evacuated. So, there is a new term which has been coined which is called urban flooding.

Now, there was nothing like urban flooding earlier, there was just flooding. Now, today we have urban flooding because this has become so typical to urban areas because we have constructed houses, we have constructed buildings even in the low lying areas, that is because we have not respected the topography. So, we respect the topography and we retain the natural slopes as much and not build in the low lying areas is what the intent of this one would be.

Another important strategy is green roof. So, we have seen in the previous lecture that the green roofs helped in reducing the amount of radiation which is absorbed by the hard surfaces, because these plants this greenery which is there on the roofs takes up all that solar radiation and the heat to make their food to carry on with their processes like photosynthesis and others.

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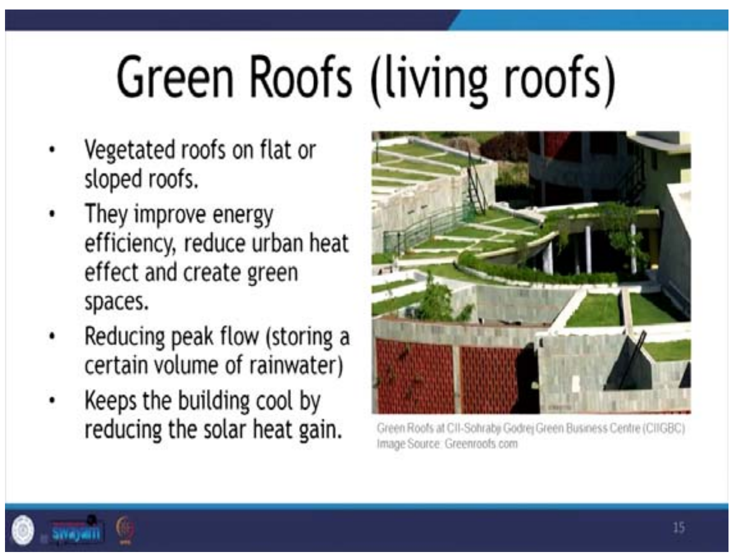

Green roofs also help from storm water point of view because they absorb one is they absorb this water. Another is they reduce the flow of the water on a surface. So, they help these green roofs they help in both the ways.

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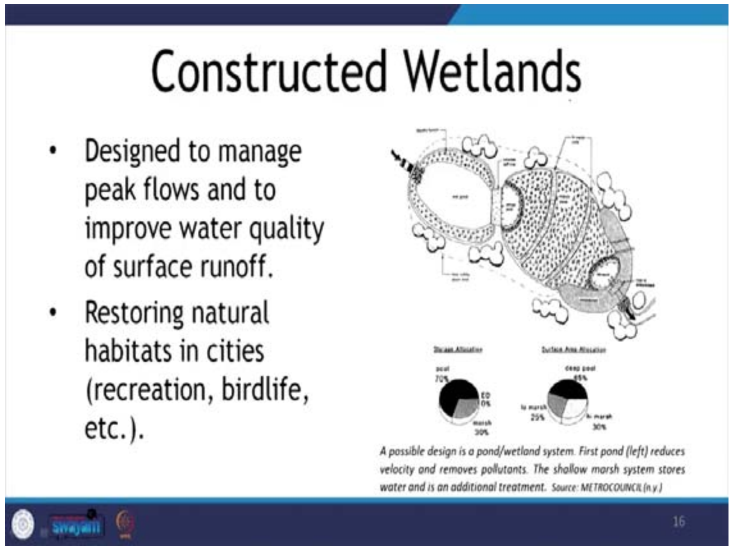

The next design strategy is constructed wetland. So, there are naturally occurring wetlands which we can preserve and retain if we are following and retaining the natural topography. But there is also this constructed wetland. So, even when there was not and existing water body within the site if we have a large site.

So, this is usually doable on a large site, so if we have a large site and on the lowest level of the site, the lower part of the site we create water bodies and we allow the runoff from the site to collect there in that part of the site which will hold which will retain the water, it can be lined depending upon the quality of the soil and then it will be allowed to channelize if it is full. So, that is what constructed wetland would be.

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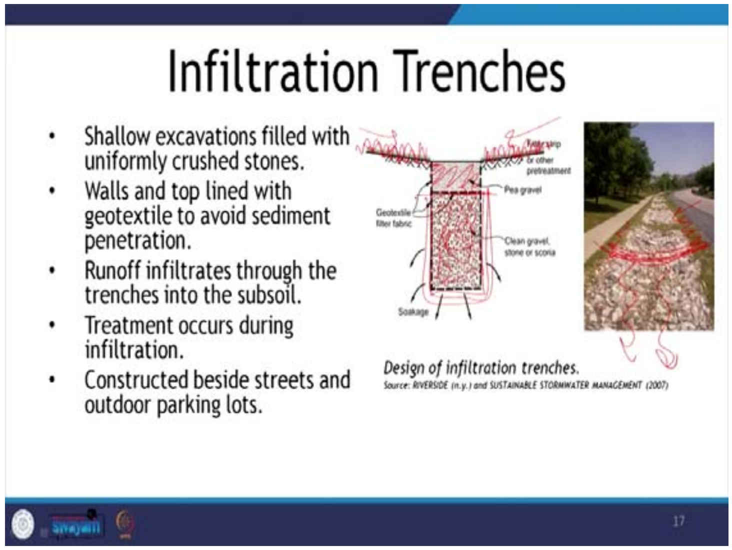

Then we also have infiltration trenches. Now, infiltration trenches are actually sort of drains, but they do not actually carry the water. These are just shallow areas as you can see in this picture. So, this is slightly shallow which will allow the water from both the sides to enter and this is this is vegetated. So, this is the filter strip which will allow for the suspended particle solids to be retained here with the help of this grass green a little bit of vegetation that you can see here.

And then, there will be the top will be lined with the small size gravel and the bottom of this trench is actually filled up with the clean gravel and bigger size gravel, and in between it is a geomembrane. So, the finer particles finer solids will actually not permeate through it and choke the lower strata.

So, when the water actually gets collected because it also it is shallow and it is a continuous trench usually we would see it along the highways. So, when the water from the highway actually reaches this trench it will be held here, retained and it will be allowed to percolate down to the ground because this media is actually loosely packed gravel and it will allow for a lot of permeability, a lot of percolation. This is what infiltration trench does.

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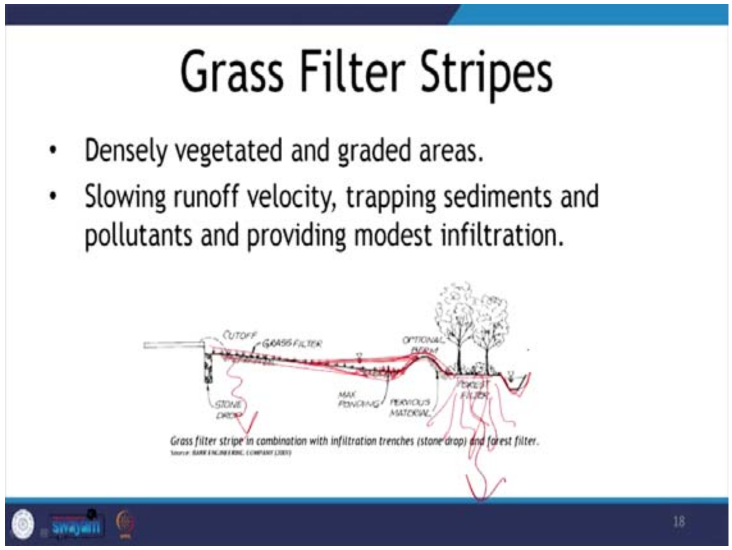

A very similar of this thing is this is again you would see near the highways and roads which is a grass filter strip. So, what we have is that we have a grass strip and this is gently sloping and there is a berm which is created, so it will hold the water. So, it is allowing for percolation. It is also allowing for retention.

So, it will be retained, this berm allows for all the solids to be retained here, and when it flows after retaining it which is again further taken into a forest filter where the roots of this these trees allow more and more of percolation down and then we can have further have an infiltration trench or a drain which may carry the excess of the stormwater. So, this is what grass filter strip does.

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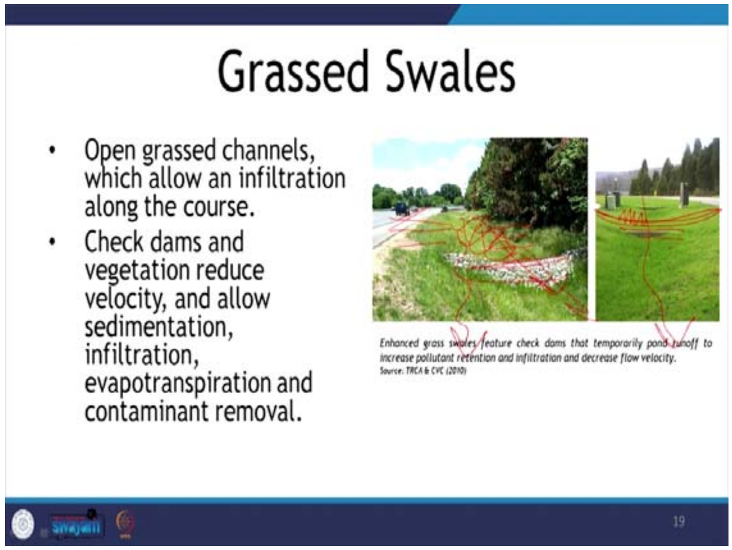

Similar is the concept of grass swales. So, just as we had we have seen infiltration trenches and these strips we also have these whales which are very common alongside the highways. So, we just allow for these areas to be covered with grass not huge trees and we also add these bunds, small barriers which will help the water to be retained here, so it will not flow and all the solids will actually be retained here.

Another function that all these swales and infiltration trenches have is to reduce the amount of pollutants going into the water bodies. Now, all the pollutants which are emitted by these running vehicles on these highways, so some will be unburned fuel, so unburned particles, then there will be other you know combusted particles, there will be fuel, petrol, diesel and all other things. So, these when they are washed with the water which is coming as storm water and if it is taken directly to the surface aquifer, so the surface aquifer will actually be flooded with a lot of these pollutants.

While, if it is retained here all these pollutants will actually be written retained here and only the water will allowed to percolate down to the ground. And even when it is flowing; even when it is flowing through the swale to the drain when the excess water comes most of the pollutants will actually be held here with the help of these barriers, these berms.

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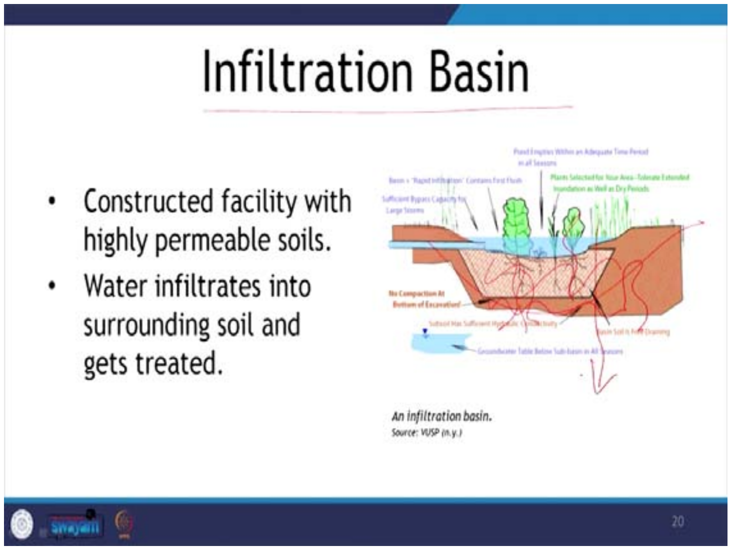

A bigger version of infiltration trench is an infiltration basin where instead of a channel we have a larger basin, but more or less similar concept where we have very loosely packed substrata and it allows water to percolate down. In addition to just gravel which we saw in infiltration trench we would have a lot of plants and vegetation the soils of which help in maintaining the looseness of this substrata and it will help us to percolate the water down.

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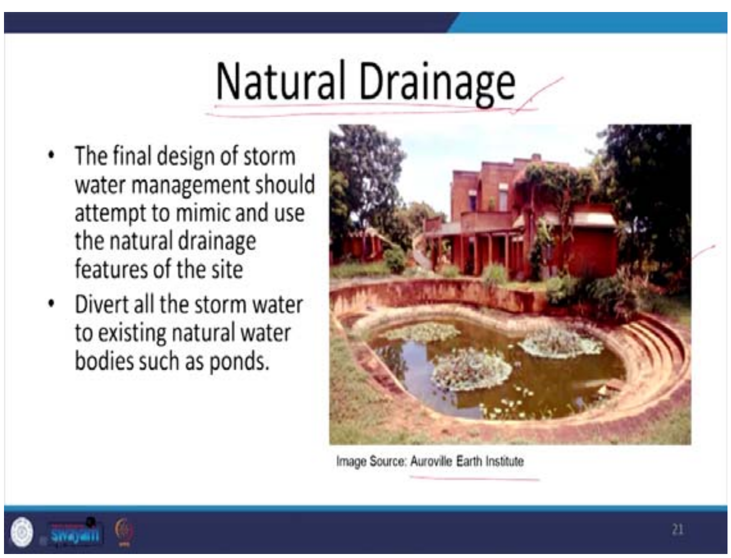

Then natural drainage. Natural drainage is retaining the drainage pattern which was naturally occurring which we have also talked about when we were talking about the natural topography.

So, if you look at the beautiful case of Auroville. So, this is only Auroville Earth Institute which is shown in the picture here, but if we look at the concept and how the entire Auroville came up developed. So, initially people followed the natural pattern of how water was flowing and then they looked at where the water needs to be intercepted, so that it does not take away the soil along and where those retention ponds, the infiltration bases and the water bodies have to be created. So, all of that will be happening, the design will be happening when we actually understand and study the natural drainage patterns which is part of natural topography study.

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So, to summarize these measures and strategies, the first one is post development runoff characteristics where we are aiming at developing the site in such a manner that the post development runoff and the conditions are same as that of pre-development ones. So, there should not be any change in the runoff as far as possible in the volume, rate, timing and pollutant load for a given site. The second one is that the final design should maximize on site storage, infiltration and evaporation of storm water, and not letting it go to the drain.

The third is to encourage reduction of pollutant load and groundwater recharge, all of these are leading to the first point which comprises of these. Then avoid discharging stormwater directly to a surface water body such as stream. Now, this will be through the drains. So, the drains will carry it to the stream or some other water body. And the most impactful of these strategies is to reduce the imperviousness and maximize the vegetation.

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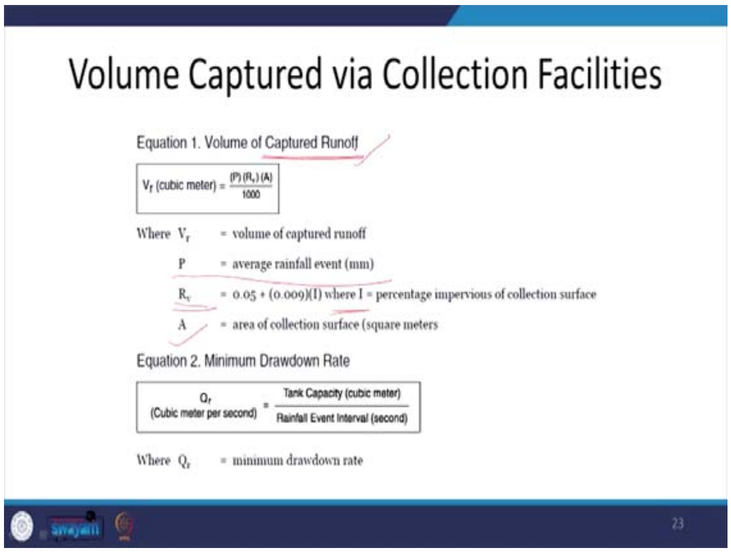

Coming back again to how green building rating programs assess your efforts through design and selection of materials. So, it has to be a tangible way in which it can be assessed it can be evaluated. Here we do that, but through the calculation of captured runoff.

Now, this captured runoff is actually a resultant of the rainfall, so it would vary from place to place. Places, dry places which have less amount of rainfall will not have as much problem as compared to the warm and humid areas which receive a lot of rainfall. And then, this is actually the runoff coefficient which is directly dependent upon the imperviousness of the surface.

Higher is the imperviousness higher is the runoff coefficient which we have seen in the previous table as well. And then the area of the collection surface. So, we are looking at reducing the total amount of runoff and if there was the runoff then all that shall be captured, captured in through creation of a tank or a retention water body, retention pond or any other thing.

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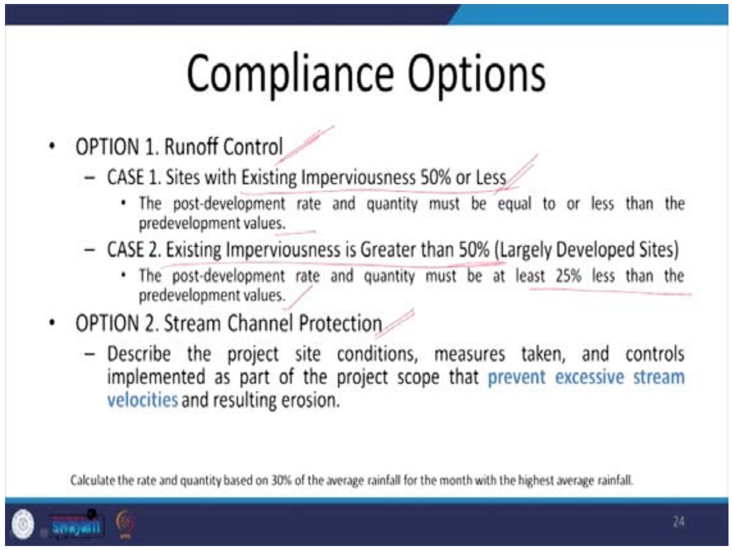

Here if you look at the compliance options, we are looking at controlling the runoff and we are looking at the stream channel protection. So, we are looking at the quantitative as well as the qualitative aspects of it and we are looking at the reduction in the flow rates of this stormwater.

So, if you are looking at the runoff control we are looking at two cases. Now, these two cases are where the sites which we are going to develop it is for a specific project site, where the existing imperviousness is 50 percent or less. So, it is a site which is less developed and there could also be a case where the existing imperviousness is greater than 50 percent which is the largely developed site which is already developed.

Now, the possibilities in this case, in the case 1, is that we would be able to retain the existing pre development conditions post development also. There is a greater possibility of doing so, while in case of a site which is already developed it is very difficult. That is why these two cases come up.

So, in case 1, the post development rate and quantity shall be equal to or less than the predevelopment values, while in case the existing imperviousness is already greater than 50 percent we are looking at a post development scenario where the rate and quantity should be at least 25 percent less than the predevelopment values. So, that is what we are looking at when we are looking at the runoff controls. So, this is one of the examples where we are calculating the volume of captured runoff.

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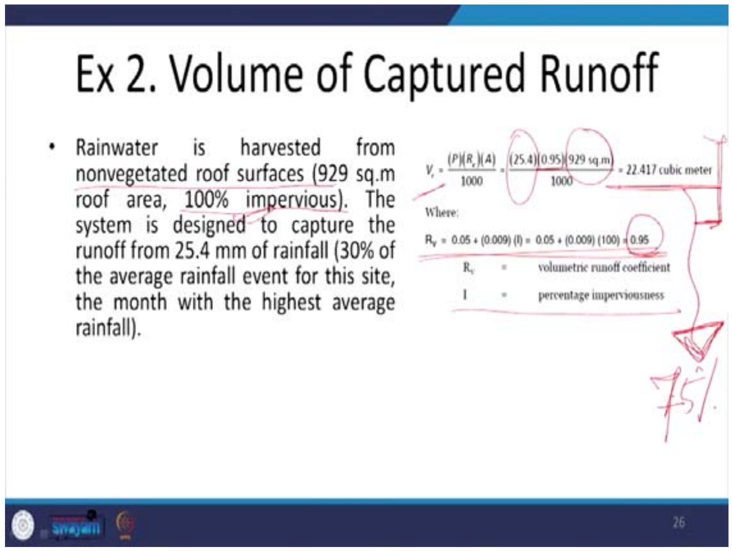

Now, this is for a roof area which is a non-vegetated roof surface. Now, this non-vegetated roof surface is 100 percent impervious. So, it allows 100 percent of the water which it receives to runoff. So, using the same equation, equation 1 of the previous slide we see that this is the amount of rainfall which is received, this is the total area of the roof and this is the runoff coefficient where through the given formula and the percentage imperviousness which here in this case is 100 percent imperviousness. So, it does not allow any water to percolate through it, permeate through it. We calculate we get a runoff coefficient of 0.95, so it means that 95 percent of the water which is received will actually be running off and we calculate the total captured runoff.

Now, for this volume of, for this volume of runoff provisions have to be made to store it, to capture it that is what it indents. Out of this if we can show that around say 75 percent of it is being retained on site or captured through the construction of a tank or any other strategy, any other measure that is what will be used for the compliance.

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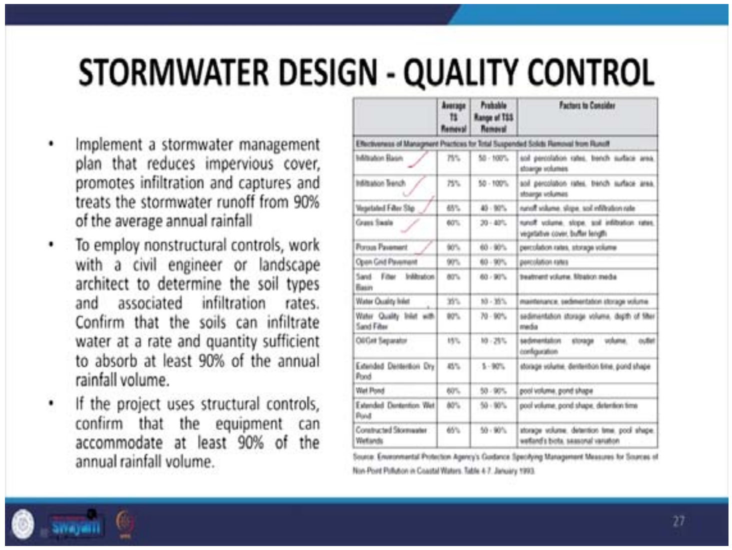

We are also talking about the quality control here because stormwater is a bigger problem when it carries a lot of suspended solids with it. So, all these strategies which we have just seen in previous slides for example, the infiltration basin, the infiltration trench, the vegetated strip, the grass swale, the permeable pavements and all of these they help in reducing the amount of suspended solids and total solids.

So, when the water is retained through any of these strategies it allows for solids to settle down as we were seeing in case of the infiltration trench or the grass strip. So, the solids the soil which is carried, the pollutants which are carried along and a lot of other solids which will be carried with the storm water when it goes with the flow, they will be held there will be retain and they will be removed from the water which further flows. So, it is not just about the quantity control, so not just capturing the storm water, but it is also about the quality control.

So, through these measures we will actually be able to manage the storm water which will be received on site, and the attempt has to be towards maintaining the pre development scenario even after the development has happened or post development as well.

So, here we stop today. And we will look at the remaining strategies and criteria which we should keep in mind when we are developing the site for sustainable development.

Thank you so much for being with us today. And we shall meet for the next lecture on Sustainable Site Development.

Thank you.