Watershed Management

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Module No. # 08

Lecture No. # 32

Urban Drainage System

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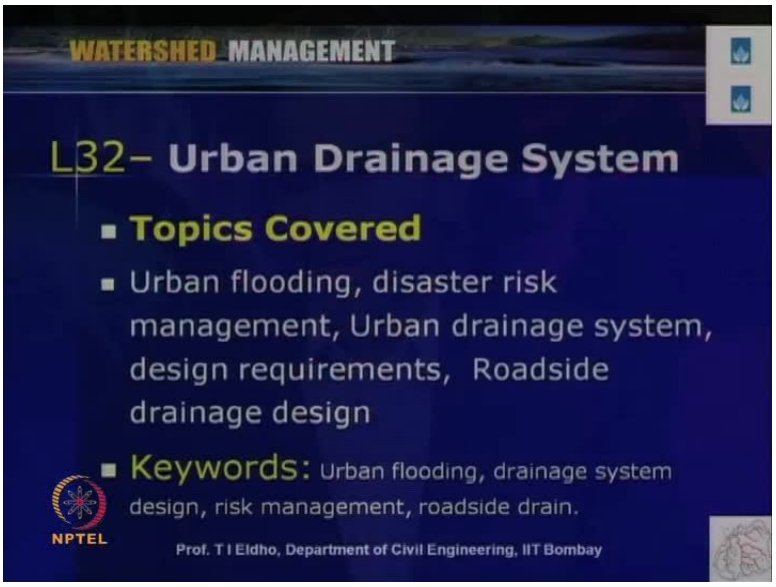

[FL] and welcome back to the video course watershed management. In module number 8, lecture number 32, we will discuss today urban drainage system. So, some of the important topics covered in this lecture include - Urban flooding, disaster risk management, Urban drainage systems, design requirements, Roadside drainage design. Some of the keywords for today's lecture - urban flooding, drainage system design, risk management and roadside drain.

So, as we were discussing earlier, so, when we discuss about watershed management, so we are taking it is as a holistic way. So, we have to see the urban areas also, and then, we have to see the storm water management within the watershed, and then, we have to see the rate of flooding and overall, say the storm water management within the system.

So, as we discussed in the last lecture, say the storm water system - we can design as separate system or combined system, and then, say whenever the urbanization takes place, there is lot of changes to the watershed and the time of concentration reduces and, the peak to the hydrograph, the peak of the hydrograph increases.

So, like that, a number of hydrological changes takes with respect to the runoff taking place within the watershed due to the urbanization. So, due to all this, as we discussed, there is good chance of, increased the chance of flooding within the watershed. So, that way, we have to, we should appropriate flood management planning as far as the watershed is concerned.

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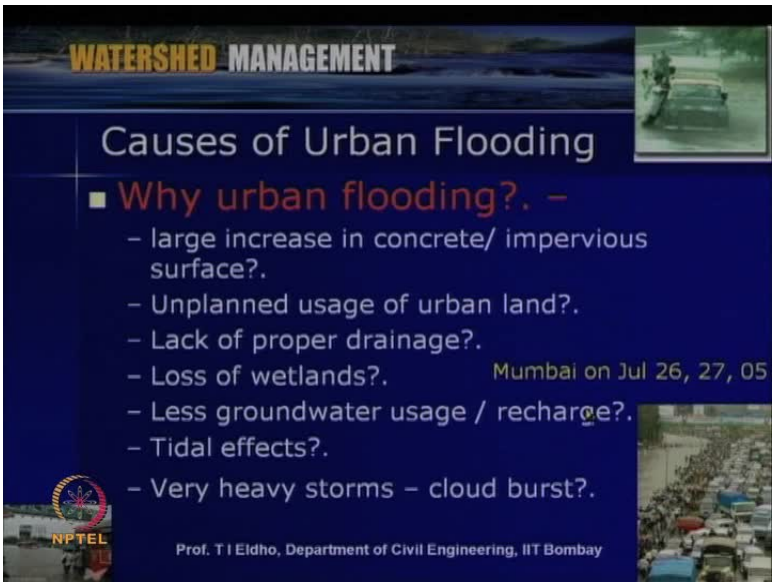

So, some of the causes of urban flooding, say here I have mentioned. So, it can be, as we discussed - a large increase in concrete in impervious surfaces or unplanned usage of urban land or lack of proper drainage or loss of wet lands or it can be less ground water usage or recharge tidal effects or very heavy storms or cloud burst or say like a climate change effect.

So, there can be number of such causes as far as urban flooding is concerned. So, say lot of changes takes place due to the urbanization to the considered watershed. So, that way, the impervious surface area increases, and then, wet lands will be lost many locations, and then, if there is no sufficient drainage or the drainage is not proper, then the chances

of flooding increases. So, that way, we can see that in most of the urbanized watershed, say there is problems of flooding. So, the problems of flooding are increasing, and then, we have to, we should have appropriate plans when we deal with the watershed management.

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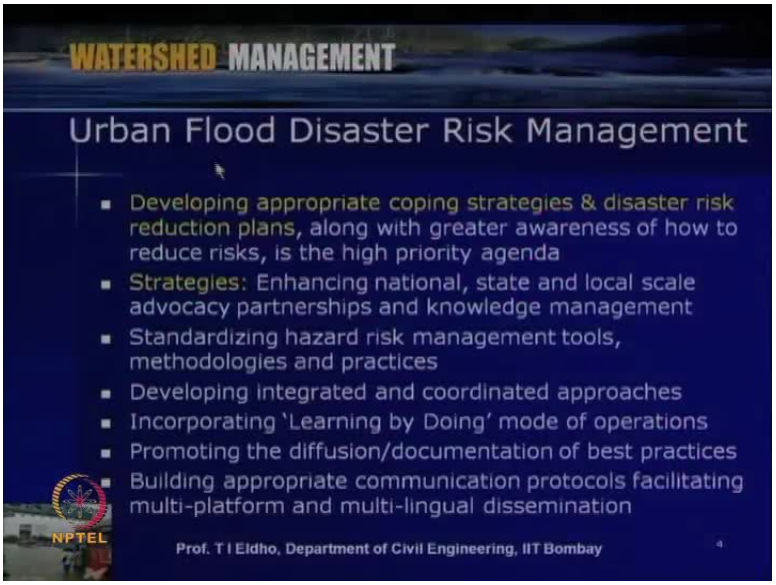

So, now, let us look into what are the things which we can do to deal with this kinds of urban flooding on a watershed basis. So, in this slide, some of the important points related to urban flood disastrous risk management are mentioned. So, as we discussed, say to deal with the this kinds of urban flooding, we have to develop appropriate coping strategies and disaster reduction plans along with greater awareness of how to reduce risk. So, that is the high priority as far as watershed developments and plans are concerned.

So, there can be number of strategies. So, strategies like we can go for enhanced national stage and locker scale, advocacy partnerships and knowledge management. So, we can get all the data's and then come up with a certain decision support systems which you can say, clearly say that what are the possible ways to reduce the flood, say urban flooding.

And then, standardizing hazard risk management tools, so, we can come up with some standard management tools and methodologies and practices to reduce the risk of urban flooding, then developing integrated and coordinated approaches.

So, as far as the flooding is concerned, as we discussed in the previous lecture also it is not only simply the storm water drainage which we have to manage but we should have a look into holistic watershed management, including LID schemes or low infrastructure development or the integrated storm water management schemes. So, like that as we discussed in the previous lecture.

So, that way, we have to standardize the management tools, and then, we can develop integrated and coordinated approaches, and then also we can incorporate learning by doing mode of operations. So, you can see that in many cities, there may be number of floods that happened in an earlier time. So, from that, we can learn a number of lessons.

Say for example, in Mumbai on July 26, 2005 there was a severe flooding. So, from that we can learn many lessons and then we can implement many changes, many things to the, to the area considered so that this flood risk can be reduced. So, that way, the learning by doing mode of operations are very helpful.

Then we can promote the diffusion or documentation of best practices. So, as we discussed in the previous lecture also, so, there are a number of best practices are possible. So, we can say come up with specific documents, say how we can reduce the risk as far as the urban flood is concerned so that we can go for better management practices.

And then, this can be, say communicated to various the stack holders including common public schools and public enterprises or the private institutions, and then also we can build appropriate communication protocols facilitating multiplatform and multi lingual dissemination.

So, as far as flooding is concerned, say if there is any area due to heavy rainfall, any other reason if there is an area which is flood prone, then we need to have appropriate communication protocols we can develop, and then, the people can be warned just like

an advanced flood warning systems, and that will be very useful to reduce the risk as far as the urban flood is concerned.

So, whenever we talk about the disaster risk management as far as urban flooding is concerned, we have to come up with appropriate plans, and then, we have to come up with appropriate guidelines with previous experiences, and then, also we have to disseminate this information to the stake holders and various agencies so that the appropriated flood warning system can be made, and so, people lives and money can be saved this way.

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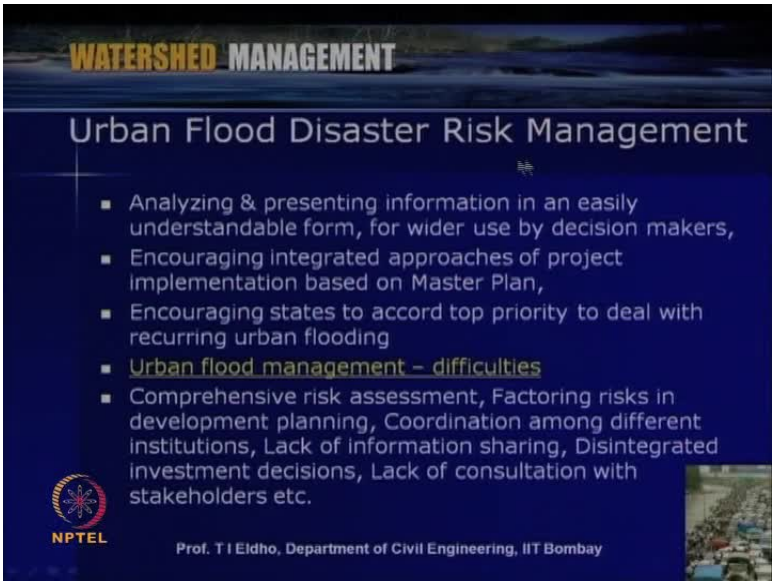

So, that way, when we discuss about the urban flood disaster risk management, we have to analyze and present information in an easily understandable form for wider use wide decision makers. So, whatever we are making as far as the guidelines or as far as the management plans, so it should be analyzed and presented in such a way that it is easily understandable to the decision makers or the politicians or the district authorities like that, and then, we can encourage integrated approaches of project implementation based on master plan.

So, each urbanized watershed is concerned, we can come up with certain master plans, and then, we can have integrated approaches as far as the project implementation is concerned so that the flood risk can be reduced, and then also we can encourage a states

to accord top priority to deal with recurring urban flooding. Say for example, government of India as central government, so the government of India can encourage state government to give top priority as far as to deal with the urban flooding since. Once urban flooding happens, say the economic loss will be very high, the human loss will be very high; so, that way we should an integrated flood risk assessment plans and we have to go for disaster risk management as far as the urban flooding is concerned.

So, whenever we deal with the urban flooding numbers of difficulties are there. So, some of the difficulties I have listed here - like a comprehensive risk assessment, then factoring risk in development planning, Coordination among different institutions, Lack of information sharing, Disintegrated investment decisions, Lack of consultation with stack holders, etcetera.

So, like that, when we would look into urban flood management, like whenever we look into disaster risk management, say number of problems are there. So, most of the time number of agencies will be working as far as the urban flood risk assessment and management is concerned.

So, we have to coordinated this agencies, and then, most of the time, these stake holders those who are affected by this floods, they will not have sufficient information; so, we have to consult with them, and then, we have to disseminate the knowledge, and then, we should have comprehensive risk assessment plan covering all the aspects with respect to the master plans as far as the urbanized watershed is concerned form the disaster risk management.

So, now, we were discussing, say when we deal with the urban flooding, it is always better to deal on a watershed scale or on a catchment scale so that hydrological unit is considered in the plans as far as the urban flooding is concerned. So, now, let us discuss the urban flood management within the perspective of watershed management.

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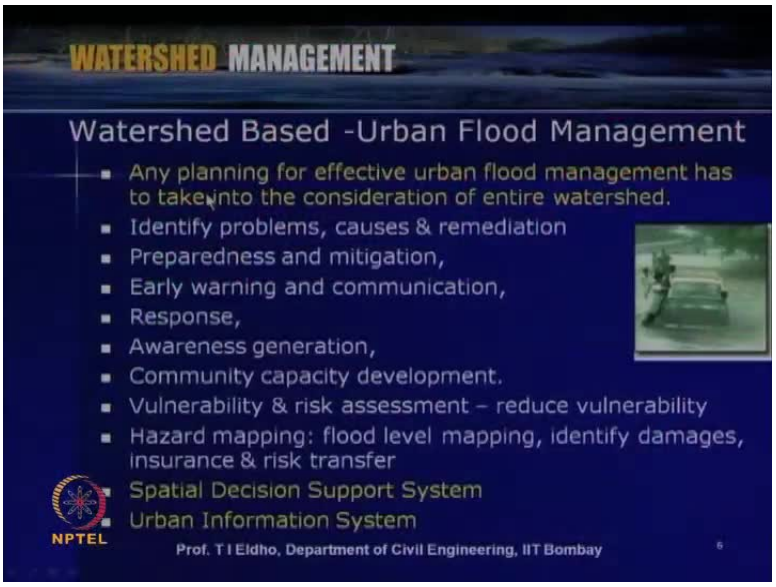

So, as we discussed any planning for effective urban flood management has to take into the consideration of entire watershed. So, since watershed is defined in such a way that it is hydrological unit wherever, the, we can have a single outlet, where all the runoff will be coming through a single outlet. So, that way, the watershed is the best unit to look into the urban flood management.

So then, that way on watershed basis, we can identify the problems, causes and we can go for various remedial measures, and then, also on watershed basis, we can go for the preparedness and then mitigation. As far as the flooding is concerned, what kind of mitigation measures to be undertaken?

And then also, since watershed is a hydrologic unit, so, when we look into early warning system and then communication, it is always better to be on watershed basis, and then, the response action also it is better to be on watershed basis. Since the response is concerned, it is with respect to deal with the discharges taking place within a watershed or the depth of flow taking place, and then also we can go for awareness generation within the various stakeholders, and that way, we can develop the community capacity to deal with such kind of flood problems.

And then also we can develop vulnerability maps and then risk assessment maps so that the total, the risk or the vulnerability due to the urban flooding can be reduced very

much. So, that way, like a hazard mapping or flood level mapping and then we can identify the damages, and then, if any, say specific locations are there, then we can go for insurance and risk transfer.

So, that way, various things are possible when we deal with the urban flood management on a watershed basis. So, it is not just like an administrate unit, just like a district or a taluk or a village, but it is always better to go on a watershed basis as far as urban flood management is concerned.

So, that way, when we deal with the urban flood management on a watershed basis, if we can develop a special decision support system which we discussed in one of the earlier lecture, we can develop appropriate special decision support system which you can show the vulnerability to flooding or the flood risk areas, and then, we can easily predict which of the area will be affected whenever the water level raises to a certain level.

And then, so that way, the decision makers can easily understand what will be happening due to certain certified intensity rainfall or predicted rainfall so that appropriate measures, management measures can be taken to save lives or to save properties.

So, that way, we can have an urban information system. Say for example, in Mumbai city after the 26July, 2005 rainfall, say a disaster management cell has been opened, and then, this cell is monitoring, say with respect to the during the monsoon season, how the very rainfall pattern changes, or with respect to heavy rainfall, what are the possibilities of flooding or what are the, which are the areas which may be affected due to flooding. So, that way, this disaster management cell gives information to the public media and that will be disseminated, and then, that way, we can have appropriate management plans.

So, that way, it is always better to develop an urban information system so that we can come up with an appropriate plans to deal with the urban flooding problems. So, now, whatever we have discussed is the urban flooding and related courses, and then what are the risk involved, and then how we can manage.

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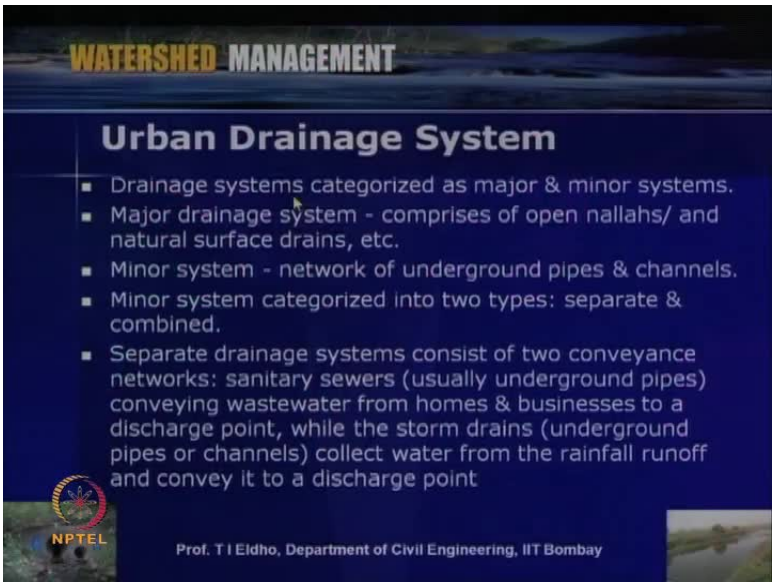

So, now, let us discuss about the urban drainage system. Since drainage pattern or appropriate drainage is given, then to a biggest, the urban flooding can be reduced. So, appropriate urban drainage system very important as far as, the, the urban flood management is concerned. So, urban drainage system, drainage system generally we can categorize into major drainage systems and minor drainage systems.

So, major drainage systems generally, say it, this comprises of open nallahs or streams and channels and natural surface drain. So, whenever rainfall takes place in the urbanized area, then this the immediately the runoff starts especially form the impervious surfaces and this will be collected through minor drainage systems just like a network of underground pipes and channels. So, that is so called minor systems.

And this minor system will be joining the major drainage systems just like a streams, nallahs, small channels or rivers. So, this, finally it will be taken to larger rivers or the, to the ocean directly depending upon the area.

So, minor system generally we can categorize into two types - like separate and combined storm water drainage system. So, this is also we have discussed in the last lecture. So, in the separate drainage system, generally there is one system to convey the storm water and another system to convey the sewage or as a separate sanitary sewers.

So, sanitary sewers usually underground pipes convey the waste water from homes and businesses to discharge point. While the storm drain, which is the underground pipes or channels collect the storm water from the rainfall runoff and convey to the discharge point. So, depending upon the city, depending upon the location, there may be separate systems or the combined system. So, the advantages and limitations of separate system and combined system we have discussed earlier.

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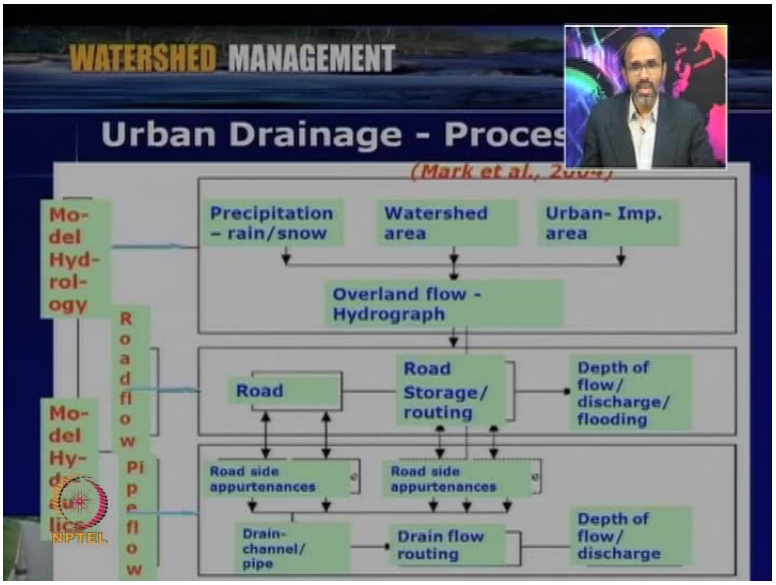

So, as far as urban drainage system is concerned, there can be major drainage systems or the minor drainage systems. So, when we look into the urban drainage processes, so we can put it in a flow chart like this. (Refer Slide Time: 18:05) So, the urban runoff is coming from precipitation or snow - precipitation as rain or snow - and then, if you consider the watershed area, there some area will be pervious area and some area will be urbanized or impervious area.

So, we should have using hydrologic models, so we can model this rainfall to runoff by considering various process like evaporation, infiltration, overland flow like that, and then, by using hydrologic models, we can get the hydrographs, so which is the overland flow as far as the considered hydraulic unit is concerned.

And then this, the hydrographs which we consider, that will be further this overland flow will be joint to the channels, or the big drains or small drains depending upon a

conditions, and this, we can model through hydraulic models. So, it can be either the flow on the road or a pipe flow, and so, that can be various, say there can be some storage as far as road is concerned or this we were to route.

And then, most of the time we have to identify how much will be the depth of flow and how much is their discharge passing or flooding taking place, and then, of course, as far as the main roads are concerned, number of appurtenances will be there; road side drains will be there, and then, say the curve roads will be there; then inlet will be there. So, like that, number of appurtenances will be there, road side appurtenances will be there.

So, this overland flow will be pass through the road to this to the appurtenances to the major drains like a drain, channel or pipe, and then, that will be routed as drain flow, and that will be the discharge which is coming to a major channel stream or river and that will be further routed. So, that way, when we discuss with the urban drainage processes, so we have to deal with the hydrological aspects and the hydraulic aspects.

So, we need to have hydrologic models, so which converts the precipitation to runoff. So, that can be mainly on for overland flow conditions, and then, we should have hydraulic models which will be routing this runoff through the roads, through the road side drains, through various appurtenances, and then, through drainage channels or pipes, and to the main drainage system or the main nallah or the streams or river

So, that is the way we have to model the urban drainage system starting from the precipitation to the runoff to the main river or channel through various overland flow conditions or road flow on the road or the small drain pipes like that.

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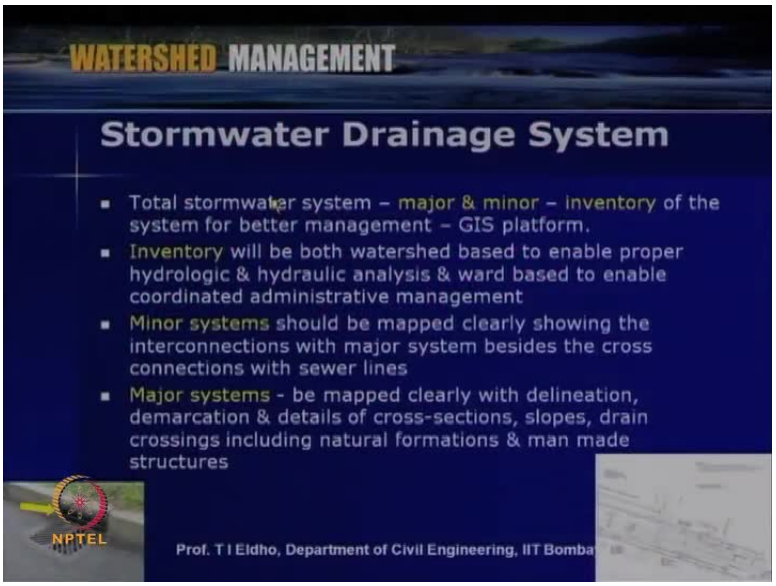

So, this flow chat shows typical hydrologic process as far as urban hydrology is concerned. So, now, let us look into various aspects as far as storm water drainage system is concerned. So, as we discussed, this total storm water system can be major storm water system or minor storm water system. Major system includes the small channels, nallahs and rivers. Minor mainly will consist pipe drains or small drains, open channel drains.

So, we should have an inventory of all this drainage system within the area which we consider. So, most of the time, we can do this through a GIS platform so that we can identify the locations easily where is the major drainage system, where are the minor systems, so like that. So, we should have an inventory, so as far as with respect to the watershed to enable proper hydrologic and hydraulic analysis.

So, ward or particular locality based to enable coordinated administrative management. So, most of the time administration is concerned, it is the administrative area will not be most of the time the watershed based. So, that way, many of these local administrations have to coordinate together.

So, it is always better to have an inventory of the drainage system, the major drainage system as well as the minor drainage system. So, as far as minor drainage systems

concerned, we should map this minor drainage systems clearly showing the interconnections with major systems besides the cross connection with a sewer lines.

So, if there is any cross connection with sewer lines for the minor storm water drainage system, that should be also clearly shown and all the interconnections should be shown, and then, where these minor systems join the major systems also should be clearly shown.

And then as far as major system is concerned, we should map clearly with delineation, demarcation and details of cross sections, then slopes, drain crossings, including a natural formations and manmade structures. So, all this, we should have appropriate inventory within a GIS platform so that whenever we are having a flood warning system which predict flooding so that we can easily identify which area will be flooded, and what kind of appropriate measures to be taken so that we can save lives and property. So, that way appropriate inventory in a GIS platform helps to reduce the flood related problems.

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So, now, let us look, we are discussing about the urban drainage systems. So, whenever we are going to design an appropriate urban drainage design, we have to meet with certain requirements. So, let us look into various aspects as far as the urban drainage design requirements are concerned.

So, the development of an adequate and functioning drainage system based on sound, hydrologic and hydraulic design principle we should have. So, we have to see the hydrologic principles so like rainfall to runoff, and then, how the flood routing all takes place. So, that we have to get through a hydraulic design. Then design of an urban drainage system requires knowledge of the catchment area and topography, then urbanization details, rainfall intensity, hydrology, hydraulics, etcetera.

So, the number of factors, number of things we have to consider when we go for urban drainage design like the catchment area, its topography, then the rainfall details, then the hydraulic details, etcetera. Then as we discussed most of the time, it is always better to go for watershed or catchment as basis as far as urban drainage design is concerned.

So, that way, we should have the contours of the watershed so that we can easily determine the boundaries of the watershed of the catchment for computing the directions of flow.

So, as we discussed earlier, based upon the contours and then the topographic details, we can come up with a digital elevation model. So, this digital elevation model as shown here - that indicates the flow directions, and then, how the, if a flood takes place, how it will be affecting the watershed.

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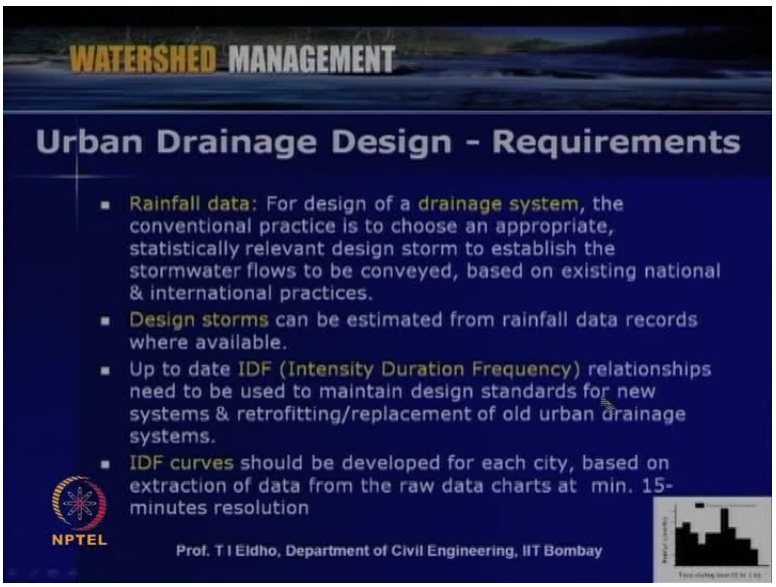

Then, as far as rainfall is concerned another important data. So, for design of a drainage system, the conventional practice is to choose an appropriate statistically relevant design storm to establish the storm water flows to be conveyed based on existing national and international practices.

So, certain codes are there - Indian standard codes or international standard codes. So, accordingly, we should consider how much rainfall intensity or intensity duration frequency curve. For example, depending upon the importance of the areas just like airport, we need maximum consideration or roads or says specified installations. So, like that, we have to consider.

Then we can also come up with a design storms which are generally estimated from rainfall data records for a long time, and then, we can come up with intensity duration frequency curves, so which shows the relationships between the rainfall intensity and then its possibility of occurrence, and this I d f curves need to be used to maintain design standards for new systems, and then also retrofitting and replacement of old urban drainage systems.

So, that way, we have to keep on updating the IDF curves and then come up with appropriate rainfall intensity while designing the new urban drainage systems or when we are going for retrofitting or replacement.

So, IDF curves should be developed for each city based on extraction of data from the raw data charts, and this can be minimum 15 minutes resolutions so that we can easily identify which are the locations for possible locations of flooding or what kind of, say how the discharge for flow depth will be varying within the watershed which we considered.

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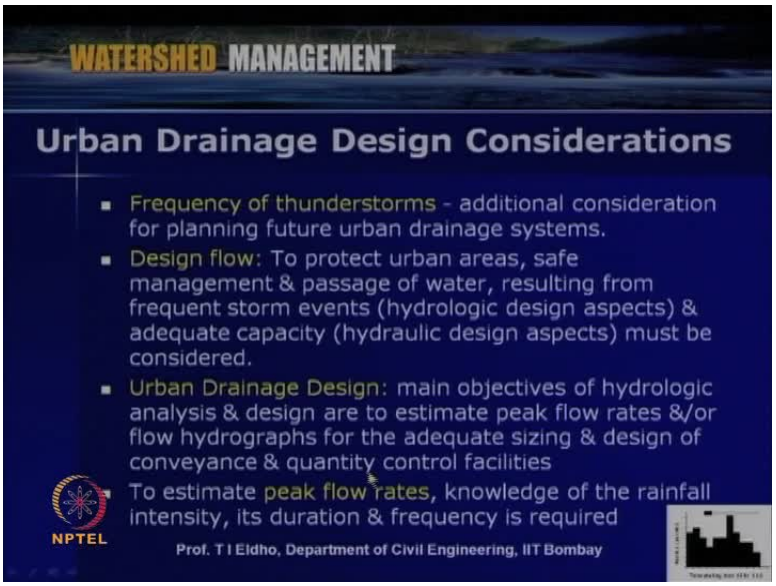

So, now, let us look into some of the important design consideration as far as urban drainage is concerned. So, some of the important considerations like frequency of thunder storms, so we should also look into additional considerations for planning future urban drainage systems, and then, as far as discharge flow, design flow is concerned - to protect urban areas, safe management and passage of water, resulting from frequent storm events like we have to look into hydrologic design and then corresponding hydraulic design.

So, there should be adequate capacity as far as the drainage system is concerned. So, we have to consider this design flow. Then urban drainage design - most of the time our main objectives include hydrologic analysis and design. To estimate the peak flow rates and the flow hydrograph or the adequate sizing and design of conveyance and quantity of control facilities.

So, as I mentioned earlier, we have two components - one is hydraulic design, second one is the hydraulic design. So, accordingly, the main objective is to do a hydrologic analysis and design. So, that gives the peak flow rate, time to peak and all those details, and then, accordingly, we design the drainage section and then its conveyance and the control facilities as far as the flood movement is concerned.

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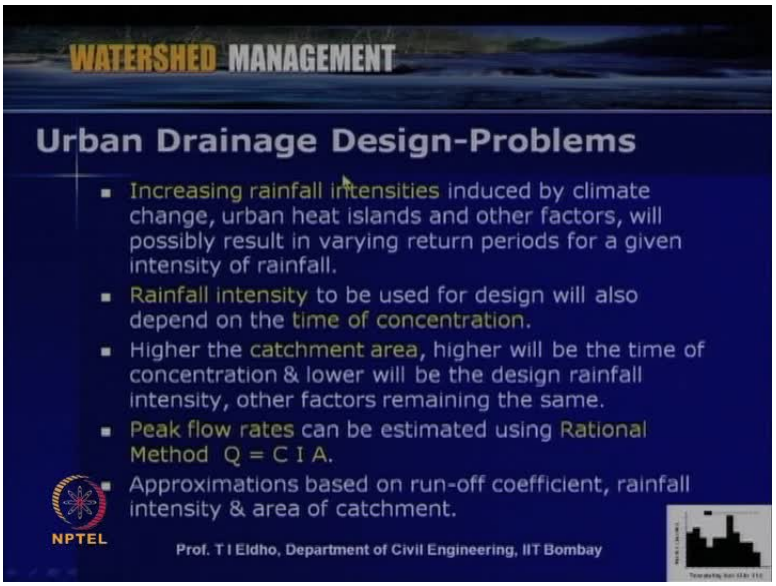

So, to estimate the peak flow rates, the knowledge of the rainfall intensity, its duration and frequency is required. So, this, we can consider the historical rainfall events, say for example, at least 10 years, and always if we can have more data like 50 years or 100 years of data, we can analyze and come up with the appropriate levels of, say as far as design flow is concerned, depending upon the area which we consider. Then when we look into urban drainage design, we have to deal with a number of problems.

So, like some of the important problems have listed here like - increasing rainfall intensities. So, in the last few decades, you see that many cities like Mumbai, Kolkata, then Chennai, etcetera are affected by high intensity short duration rainfalls, and this rainfall causes heavy flooding and large losses as far as the human life and property are concerned. So, this can be due to various reasons like rock burst or the urban heat Islands problems or climate change impacts.

So, that way, we have to deal with increasing rainfall intensities induced by climate change, urban heat islands or other factors which will possibly result in varying return periods for a given intensity of rainfall, and then, rainfall intensity to be used for design will also depend upon the time of concentration.

So, we have to identify how much is the time of concentration as far as the considered watershed by considering the various parameters, and then, if higher the catchment area,

higher will be the time of concentration and lower will be the design rainfall intensity; other factors remaining the same, but we have also have to see the effects like a tidal effects, for example, in cities like a coastal cities like Mumbai or Chennai are affected by the tidal effects also. So, we have to see simultaneously not only related to the rainfall runoff pattern but also the tidal effects.

As far as peak flow rates are considered, we can simply use methods like rational method which is Q is equal to C into I into A, where A is the area of the catchment, I is the intensity of the rainfall, C is the coefficient of runoff. So, this symbol formula we can utilize for hydrologic analysis, and then, as far as this rational formula is concerned, approximations based on runoff coefficient and rainfall intensity and area of catchment. So, that way, we can easily do calculations and designs as far as the hydrology is concerned.

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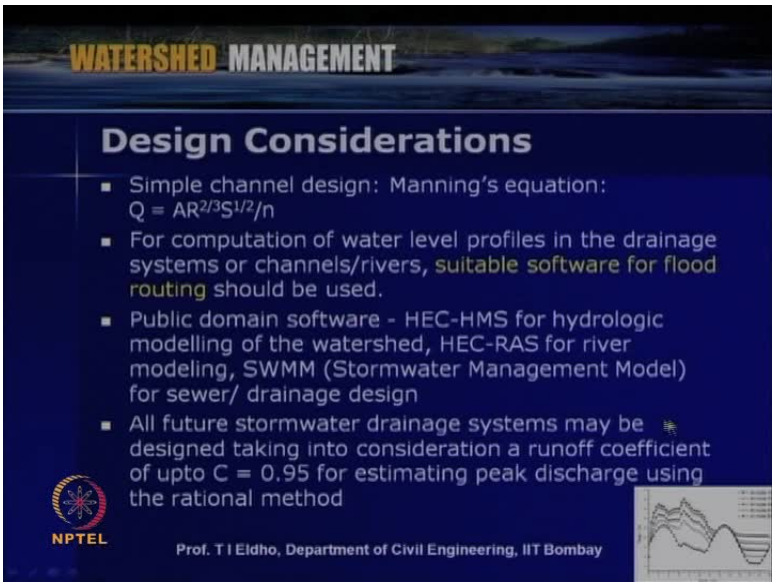

And then, hydraulic design - just like the cross section of the drainage system. We can use simple equations like Manning's equation or Chezy's equations for simple design.

But whenever we are looking for the routing - flood routing - is concerned, we have to go for numerical techniques and software's like HEC-HMS or HEC-RAS type of modeling tools. So, for simple channel design, we can use Manning's equation like Q is equal to A into R to the power 2 by 3 S to the power 1 by 2 divided by n, where n is the

Manning's roughness coefficient; A is the area of cross section; R is the hydraulic radius and S is the slope.

For computation of water level profiles in the drainage systems or Channel Rivers, say we can go for suitable software's for flood routing just like public domain software's like HEC-HMS for hydrologic modeling of the watershed; then HEC-RAS for river modeling or we can go for software like SWMM - storm water management model - for sewer drainage design.

So, that way, we can either go for a simple modeling model just like a rational formula or Manning's equations or we can go for somewhat complex models like HEC-HMS or HEC-RAS which consider most of the physical parameters as far as the rainfall runoff is considered.

So, all future storm water drainage system may be designed taking into consideration a runoff coefficient up to C is equal to 0.95 for estimating peak discharge using the rational method. If you are using rational method, so maximum possible generally we can consider 0.95.

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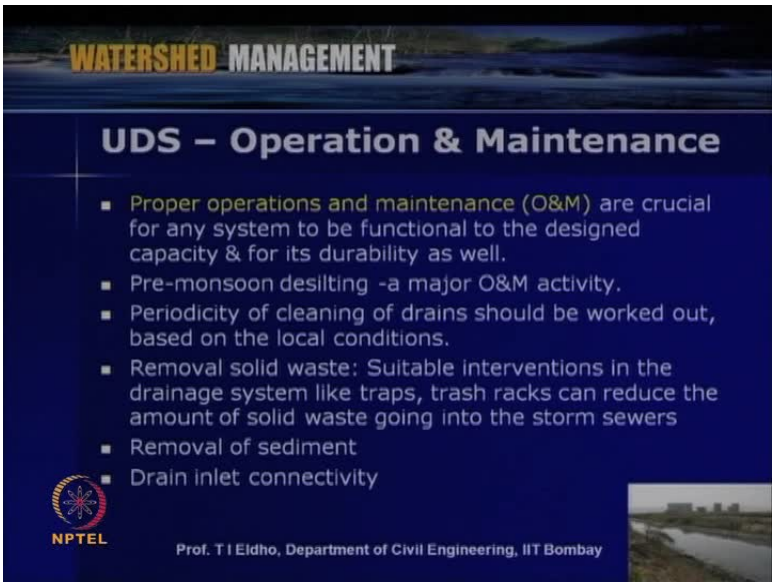

And then urban drainage system is concerned, there we should deal with the operation and maintenance. So, it is not only appropriate design and then implementation, but the operation maintenance also very important.

So, let us look into some of the important aspects as far as the operation and maintenance of the urban drainage system. So, proper operations and maintenance are crucial for any urban drainage system to be functional to the design capacity and for its durability as well.

So, you can see that whenever heavy rainfall or the monsoon takes place, say for example, in India, during the monsoon period of 4 to 5 months starting from June to September or October, so we cannot do many of this maintenance during that time. So, we have to do this maintenance work before the monsoon starts. So, that way, pre monsoon desilting a major operation maintenance activity in most of the cities and watersheds.

Then periodicity of cleaning of drains should be worked out based on the local conditions. So, as I mentioned local conditions like if there is effect of tides or other kinds of parameters which we have to consider, then we have to see whether we have to do before monsoon only or periodically we have to do.

And then, other issues like removal of solid base, so you can see that many locations, say the drains will be clocked to the solid base; so, there should be suitable interventions in the drainage system like traps, trash racks, which will reduce the amount of solid base going into the storm sewers.

And then also in many of the storm drainage systems, we can see that sedimentation is a problem silting is a problem in channels or even pipes. So, we have to see various arrangements like removal of sediments within the drainage systems.

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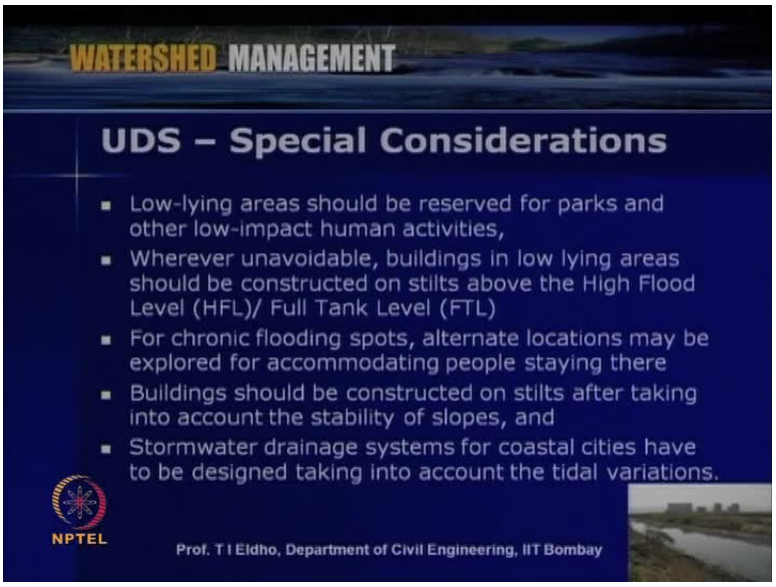

So, sometimes hydraulically also we can do this through maintaining certain minimum velocity within the drainage system or we can also remove it manually, and then also we have to see the inlet connectivity between the major drains and then minor drains, and then, we have to see how these system to worked out.

And then also as far as the urban drainage system is concerned, some of the special considerations which we have to see as far as the watershed is concerned - like low lying areas should reserve for parks and other impact human activities should be only done; then wherever unavoidable, buildings in low lying areas should be constructed on stilts above the high flood level or full tank level.

Then for chronic flooding spots, alternative locations may be explored for accommodating people staying there, and then, a building should be constructed on stilts after taking into account the stability of slopes, and then, storm water drainage system for coastal cities have to be designed taking into account the tidal variations.

So, when we look into urban drainage system, we have to see all this considerations like a tidal effects, then low laying areas, and then, if any specific areas always flood prone, then what kind of measures we can consider like that. So, various special considerations we have to see as far as urban drainage system design is concerned.

So, now, whatever discussing is the important aspects as far as urban drainage system - its consideration is design and its requirements. So, that is what we are discussing. So, now, one of the important urban drainage system generally in urban areas is the road side drainage system. So, if you have appropriate road side drainage system, we can see that in most of the urban areas, we can reduce the flooding problems to certain extent.

So, as I mentioned earlier, there was a heavy flooding in on 26 July, 2005 in Mumbai due to cloudburst effects of rainfall of about more than 940 mm in a time span of 24 hours, and then also high tidal effects. So, due to this, there were heavy flooding in many locations of Mumbai city, and number of people died and then there was huge economic loss.

So, that way, then we was as to look into the roadside drainage system. As far as the Mumbai city is concerned, most of the important roads of Mumbai city are concerned. So then, we looked into various design aspects of various existing conditions as far as this Mumbai roads are concerned, and then, we went through all the design procedures as far as roadside drainage design in concerned.

And then, we come up with certain guidelines. So, I will just discuss this roadside drainage design within this contest of Mumbai roads which we redesigned few years back by considering the various rainfall conditions, tidal conditions, and then the road conditions and the side conditions.

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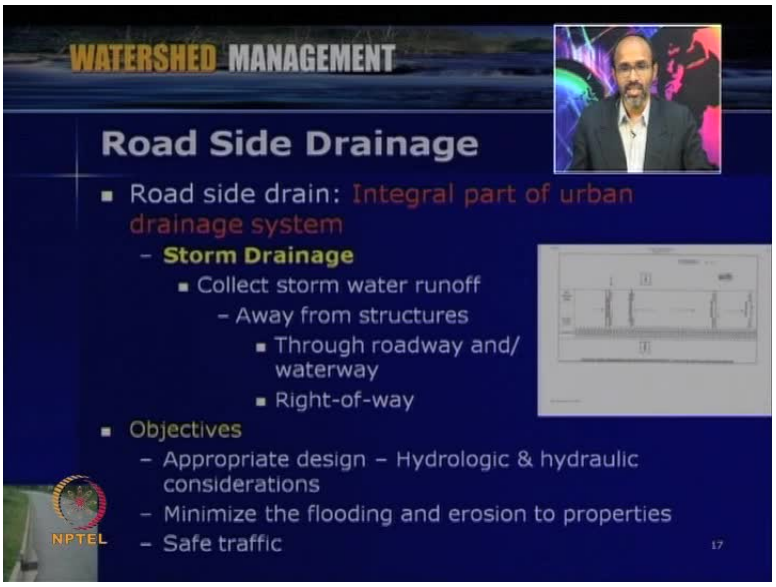

So, some of the important aspects are listed here. So, as I mentioned roadside drain is integral part of urban drainage systems, so this is actually storm drainage. So, whatever the storm water from the nearby areas, it will be mainly coming through these roadside drains, and then, it will be going to these larger drainage systems or the nallahs or channels. So, the storm drainage here what is happened? We collect the storm water, runoff, then this should be away from structures and through road way or the waterway or right of way.

So, you can see that if this is a, the road, then we have to collect all the storm water coming from adjacent areas, and then, generally ,the drainage system storm water drains will be on the sides of the roads, and then, we have to see appropriate design as far as the roadside drainage system is concerned.

So, some of the important objectives for such a design is hydrologic. We have to see the hydrologic aspects like rainfall to runoff; then we have to see the hydraulic considerations like what kind of sections to be given, what kind of drain; - open drain or pipe drain – so, what kind of drain is to be given. So, the main objective will be minimize the flooding and then erosion to properties and then save traffic.

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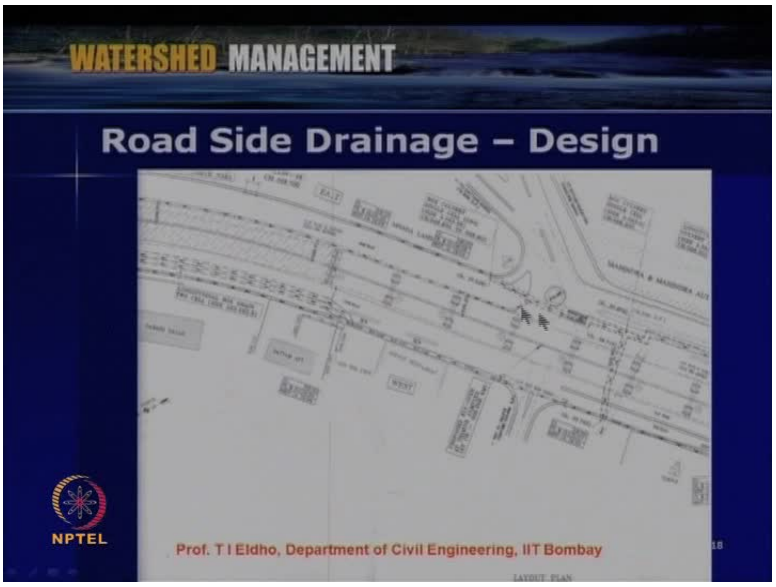

So, in urban area, if we can reduce the flood risk through all the roads, then most of the inconveniences cause due to urban flooding can be reduced to a larger extension. So, that way we have to see, when we design the roadside drain, we have to see the road layout and then various junctions, various flyovers, and various natural drains coming, and then, wherever the cross drainage systems and then the directions, then the slope. All this important aspect we have to consider when we look into road side drainage design.

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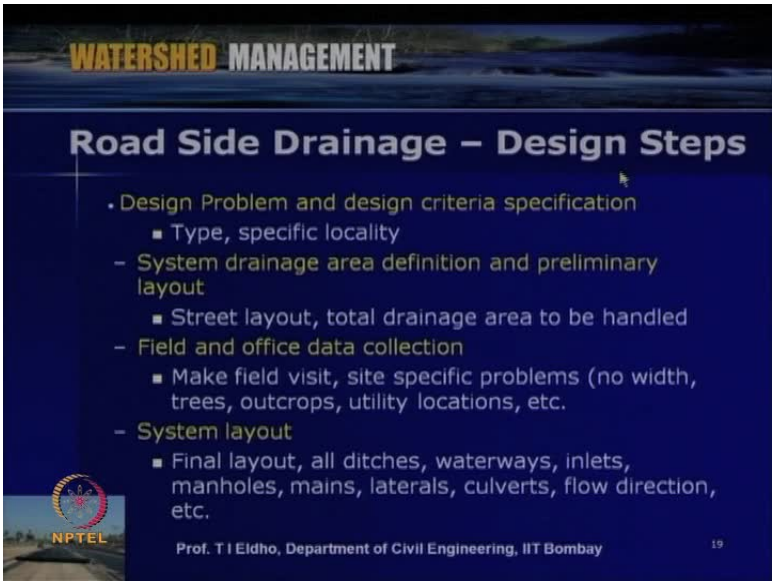

So, as I mentioned, we have formulated the design steps. So, some of the important design steps we have discuss here. So, design problem and design criteria specification - we should see what kind of design we are looking for; then what kind of locality, whether just like a crowded place like Mumbai where small city, where not much crowd is there. So, accordingly, we have to see the roadside drainage design.

Then the system drainage area definition and preliminary layout – so, we should get the road layout; accordingly, we should go for the drainage and then the drainage area; then we should get the street layout, total drainage. Then field and office data collection – so, we should go to the field and then see the specific problems like the width whether in trees, have their outcrops, utility, locations, etcetera. Then we should come up with the system layout.

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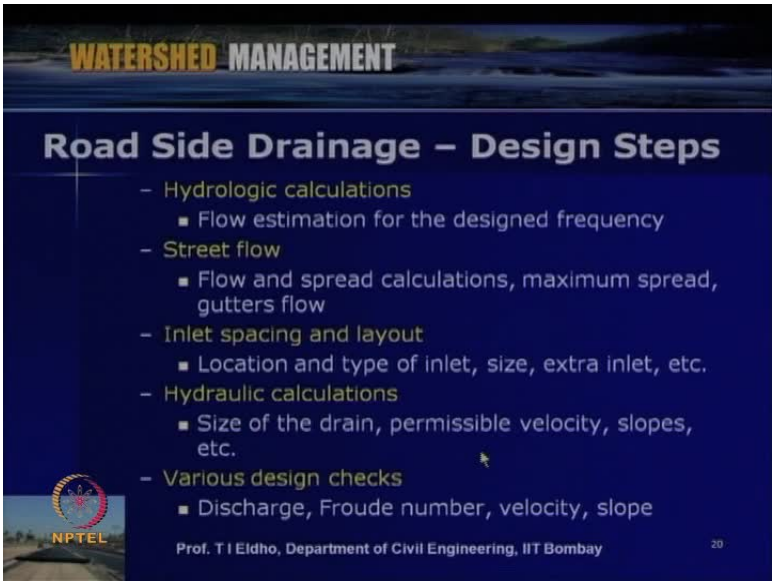

So, the final layout, we should have like all ditches, waterways, inlets, manholes, mains, laterals, culverts, flow direction, Etcetera. So, we have to go systematically. Then, next step is hydrologic calculations. So, we have to identify as far as roadside road is concerned, so how much water will be coming from both sides. So, we have to see that area and then how much is a rainfall possible.

And then, we should go for hydrologic calculations. So, we may have to go for hydrologic modeling, rainfall runoff. So, flow estimations for the design frequency we

have to consider. So, we have to see the intensity duration frequency curve or return periods, which we have to consider 2 years return period or 5 years return period or 50 years return period, like that.

Then we have to see the street flow, like flow and spread calculations, then maximum spread, gutters flow, like that. Then inlet spacing and layout, so like location and type of inlets size extra inlet, etcetera.

Then we have to see the hydraulic calculations like size of the drain, permissible velocity, slopes, etcetera. Then various design checks like Discharge, Froude number, velocity, slope, like this. All this parameters we have to consider as far as the roadside drainage design is concerned. So, it is not only hydrologic aspects but also the hydraulic aspects like size of the drain, velocity, slope, etcetera.

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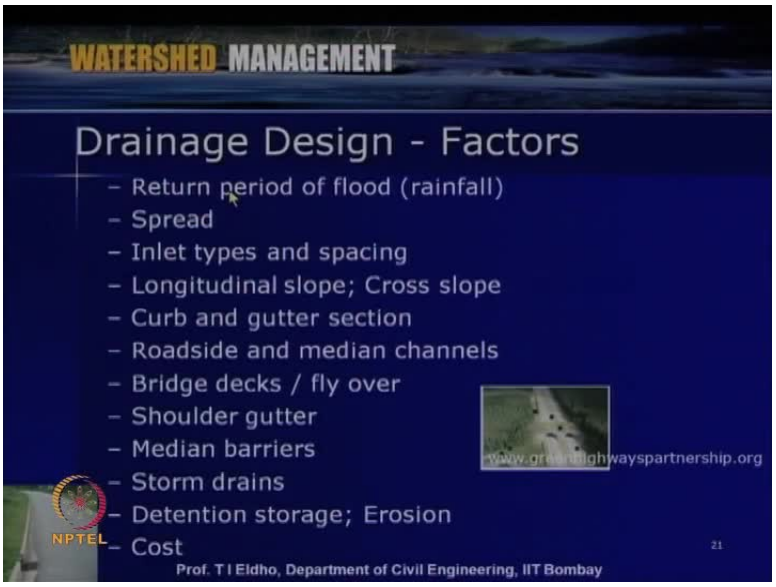

So, some of the important factors which we have to consider when we go for roadside drainage design are listed here - like written period of flow, like 2 years written period or 5 years written period or 50 years written period. So, this depends upon the city area and then the importance of the area. Then the water spread area like when we consider the road, both sides how much area whether it is on a watershed basis or only a strip wise, both sides like 50 meter or 100 meter both sides of the roadside.

Then inlet types and spacing – so, how these flow is coming to the, to the road side drains, so and then, what is the spacing for that. Then longitudinal slope, we have to see then cross slope. Then curbs and gutter sections - so, how the curbs, and how the gutters, how this is considered. Then roadside and median channels, bridge decks flyover, shoulder gutter, median barriers, storm drains, detention storage, erosion, and then, what is the cost, how much cost. What are the financial layout as far as; whether we have to go for vary expensive drainage systems or how we can reduce the cost. So, all those issues we have to consider.

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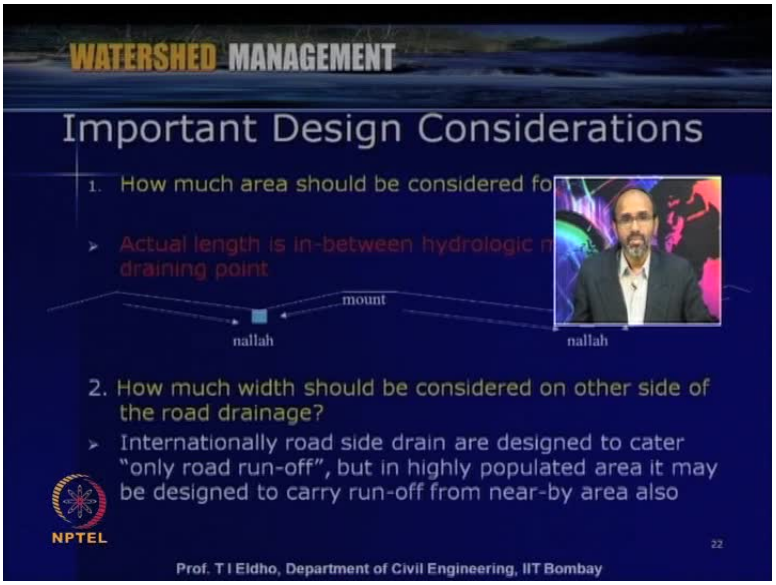

So, these are some of the important factors which we have to consider when we deal with the drainage design. So, some of the important design considerations I have listed here - like how much area should be considered for a reach. So, if this is the mount which we consider, then both sides how much area we have to consider. So, actual length is in between hydrologic mount to the drainage point; so, this is the drainage point; so, this is the hydrologic mount; so, how much area we have to consider? (Refer Slide Time: 47:03)

Then second issue is how much width should be considered on other side of the road drainage. Internationally roadside drain are designed to cater only road runoff, but in highly populated area like Mumbai, we have to consider the runoff coming from nearby

areas also. So, nearby properties or this runoff will be coming to the roadside drains, so, we have to deal that also.

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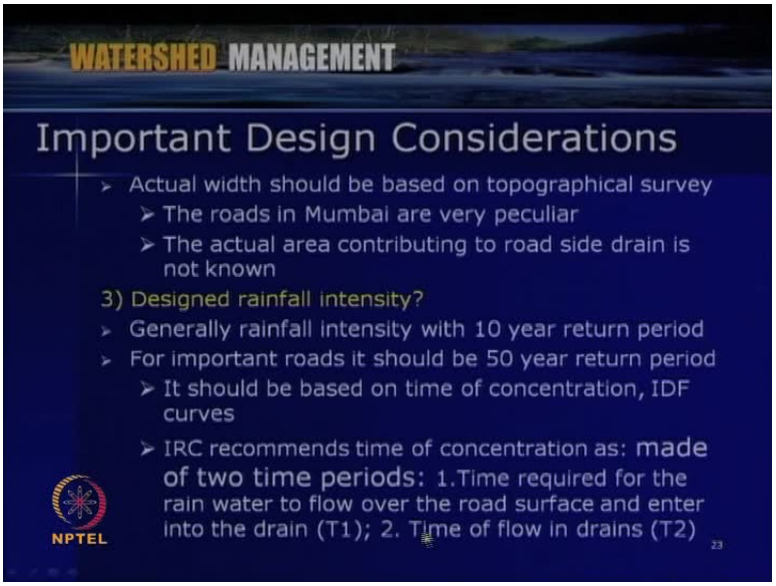

So then, actual width should be based on topographical survey; then the roads in Mumbai for example, we have to see the actual area contributing to road side since it is heavily populated, and then, the roads are very narrow. So, that way, we have to consider.

Then third issue which we have to consider is design rainfall intensity. Generally rainfall intensity with 10 year return period is considered. For important roads, it should be about 50 year return period like roads connected to airport area, like that. Then should be based on time of concentration and then intensity duration frequency curve.

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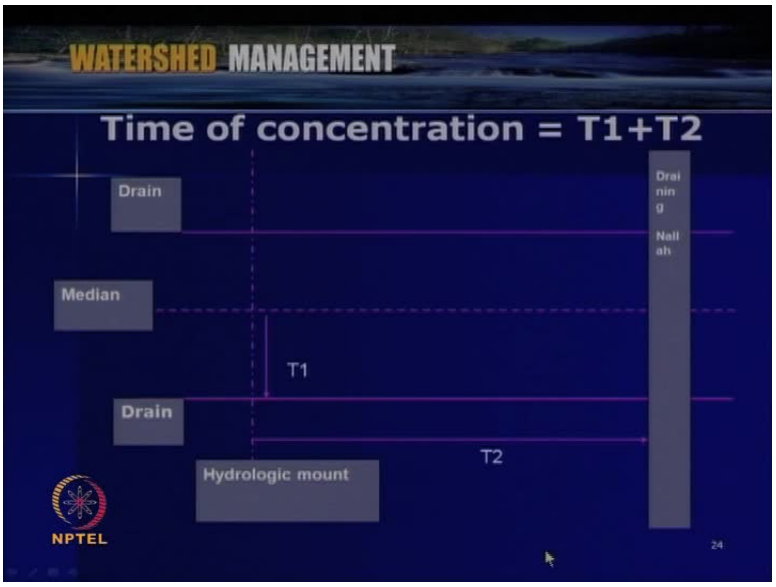

So, Indian road contracts, for example, recommends time of concentrations made of two time periods - one is the time required for the rain water to flow over the road surface and enter into the drain, and then, time of flow in the drains. So, this is demonstrated, so, this is central line of the road this is the road. So, this is T1 the time this flow to end up to this roadside drain, and then, T2 is this how much time reach the main drain or nallah or the channel. So, that way, we have to consider the time of concentration is equal to T1 plus T2.

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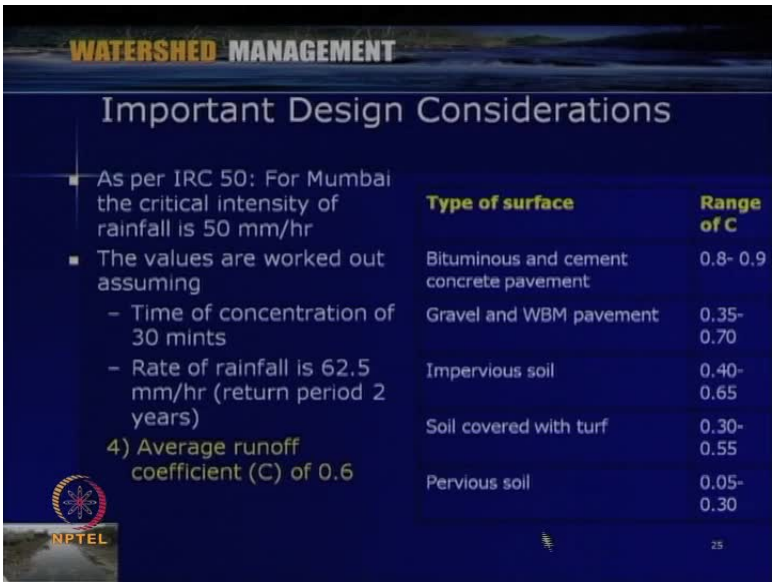

So, some of the important design considerations, for example, if you consider Indian road congress manual number 50, for example, Mumbai they suggest minimum 50 mm per hour rainfall, then the values are worked out assuming time of concentration of 30 minutes; then rate of rainfall is 62.5 mm per hour with return period of 2 years, and then, average runoff coefficient to be considered 0.6.

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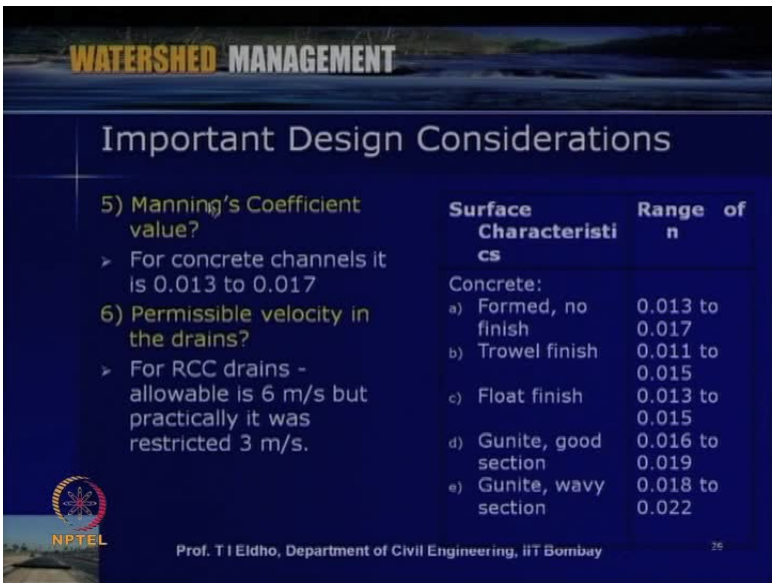

So, these are the details as given in IRC 50, and then, like type of surface, like bituminous, the runoff coefficient can be 0.8 to 0.9; impervious soil 0.40 to 0.65. So, like that, depending upon the area, we can considered the runoff coefficient. Then as far as hydraulic design is concerned if we use the Manning's equations, then Manning's coefficient value we have to consider.

So, if it is concrete channel, then it can vary from 0.013 to 0.017. For various surface characteristics range of n is given here. This we can get from standard literature.

Then next important design consideration permissible velocity in the road drains. As far as RCC drains if you consider, allowable maximum velocity 6 meter per second and minimum velocity up to 30 centimeter per second, and but even the 6 meter per maximum is allowed, but restricted generally to 3 meter per second as per Indian road congress records.

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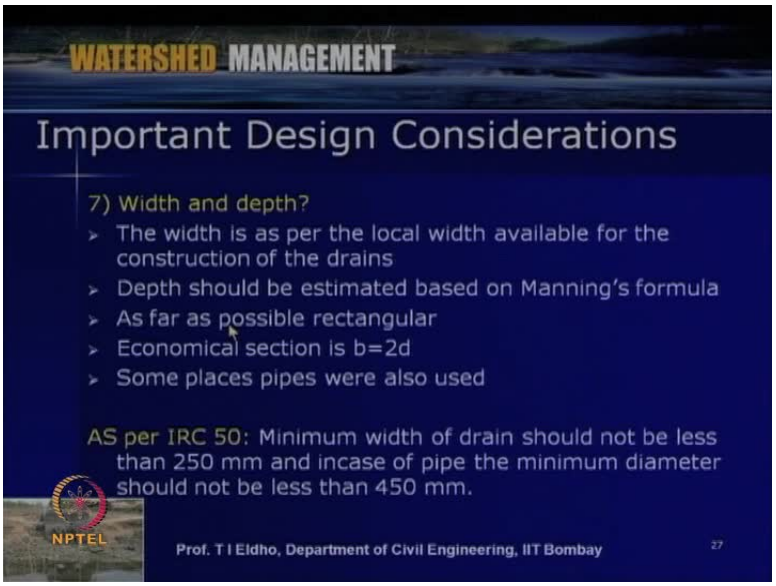

Then another important aspect is width and depth. So, the width is as per the local width available for the construction of the drains; then depth should be estimated based on Manning's formula. As far as possible, we can go for rectangular drains. Then economical section is the width is equal to 2 times depth, and some places, we may have to if we are going for open drains; some places we may have to go for further pipe drains.

Then as per IRC 50, a minimum width of drain should not be less than 250 mm, and in case of pipe, the minimum diameter should not be less than 450 mm. This is as per Indian road congress manual number 50.

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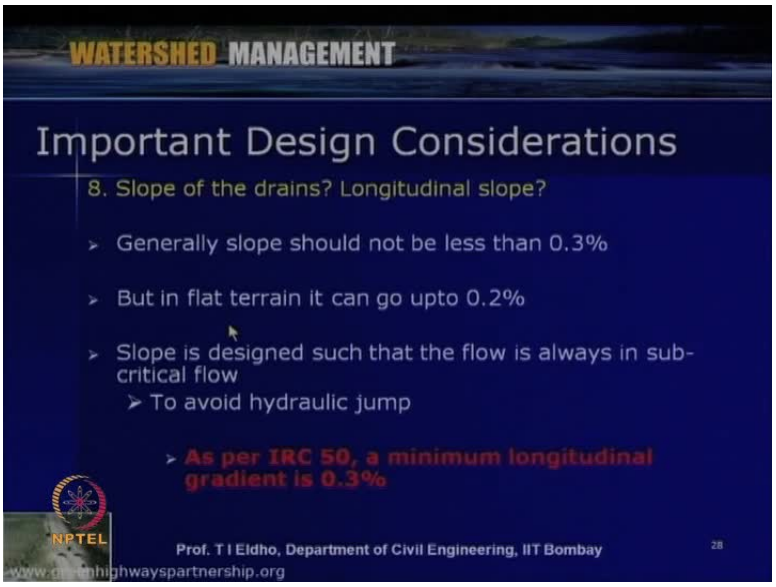

Then eighth point is slope of the drains like longitudinal slope. Generally slope should not be less than 0.3 percent, but in flat terrain it can go up to 0.2 percent, and slope is designed such a way that the flow is always in subcritical flow. So, there should not be any supercritical flow condition so that there is any hydraulic jump can takes place. Within a channel, that may create further flooding problems.

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So, as far as IRC 50 code, minimum longitudinal gradient is 0.3 percent. Then free broad also we have to when we go for open channel type design, 0.3 meter is the prescribed

free board, but for example, in city like Mumbai, the flat terrain and does not allow to have more free boards. Then IRC recommends like if the bed width is less than 300 mm, free board minimum should be 10 centimeter; 300 to 900 mm - 15 centimeter; 900 to 15000 mm - 30 centimeter, and for larger size, it should be 90 centimeter, so, like that.

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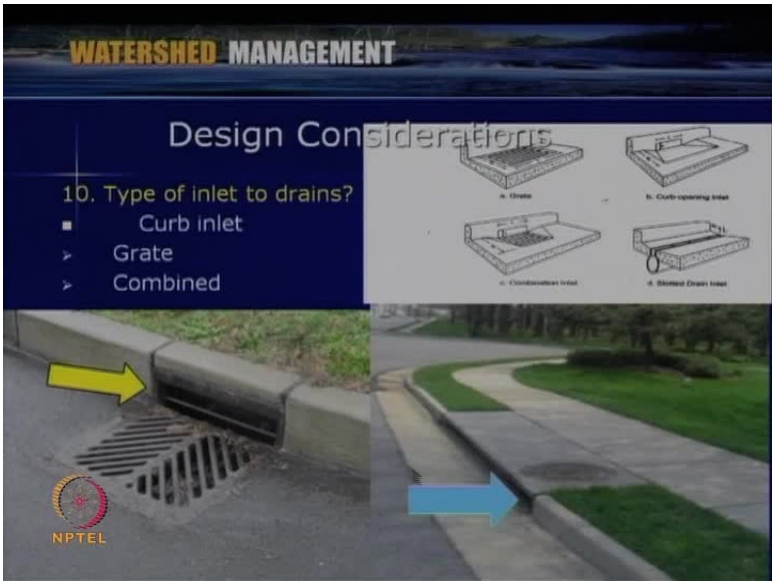

Then design consideration like type of inlet to drains. So, we can have either curb inlet or we can have grater inlet or we can have combined inlet. So, we should have depending upon the terrain, depending upon the location, we should go for the best possible type of inlet to the drains.

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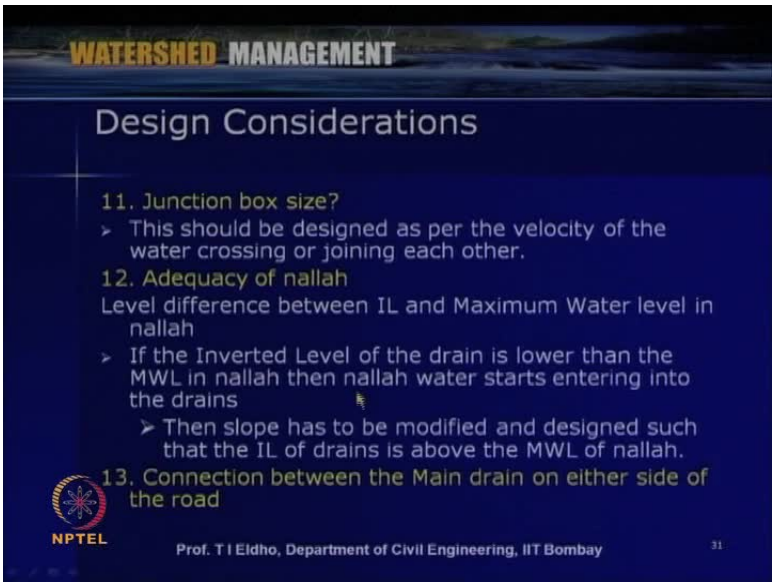

Then like a junction box size, this should be designed as per the velocity of the water crossing or joining each other. Then as far as the nallahs concerned, all this small drains water will be taking to the nallahs or the streams. So, level difference between the invert level of the invert level and maximum water level in the nallah. We have to see if inverted level of the drain is lower than the maximum water level in nallah, then nallah water starts entering to the drains. So then, slope has to be modified and design in such that the invert level of drains is above the maximum water level of nallah.

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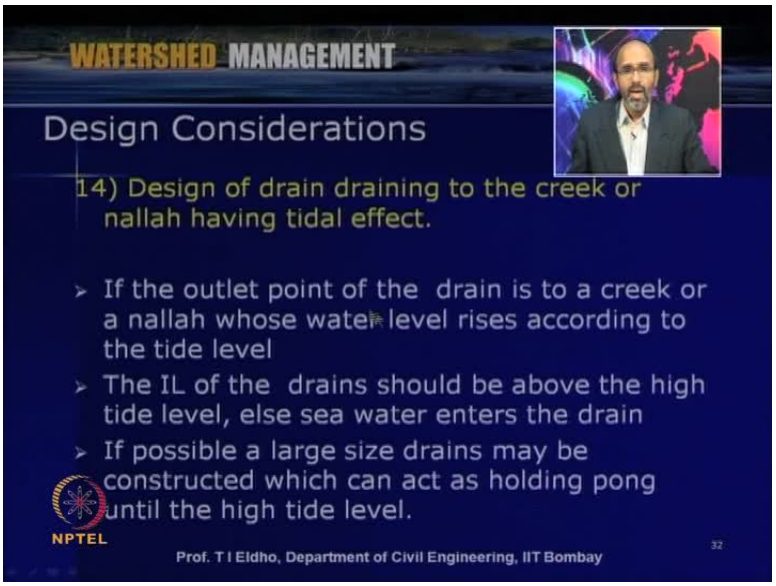

Then connection between the main drain or either side of the road, we have to see. Then, points, important points like design of draining to the creek or nallah having tidal effect. So, as I mentioned in a city like Mumbai, tide is an important factor as far as flooding is concerned.

So, we have to see that whether the outlet of the drain is to a creek or a nallah whose water level rises according to the tidal level. The invert level of the drain should be above the high tide level else see water may enter to the drain. If possible, a large size drain may be constructed which can act as holding pong until the heighted level.

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Then we need a large quantity of data when we go for the road side drainage system design or the urban drainage design. So, some of the important data like rainfall intensity, then runoff coefficient, area contributing to drains, then cross sectional parameters, the reduced level of the hydraulic mount, then reduced level of the ground level, invert level of the drains. So, like this, all this data required as far as the drainage design is concerned.

Then key plan of the work, the area, like the length, location of the nallah, size, invert level of drains, at starting point and draining point slope between the sections, other major drainage work nearby or river nearby. So, all these key plan should be available.

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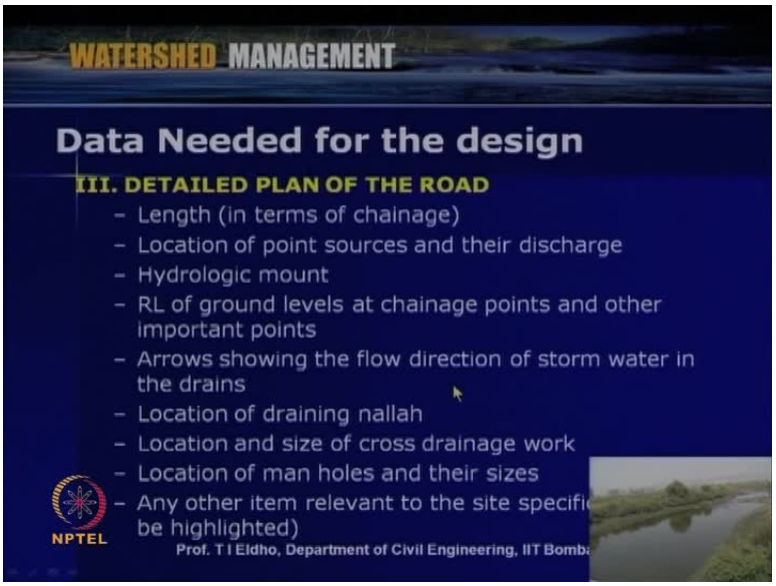

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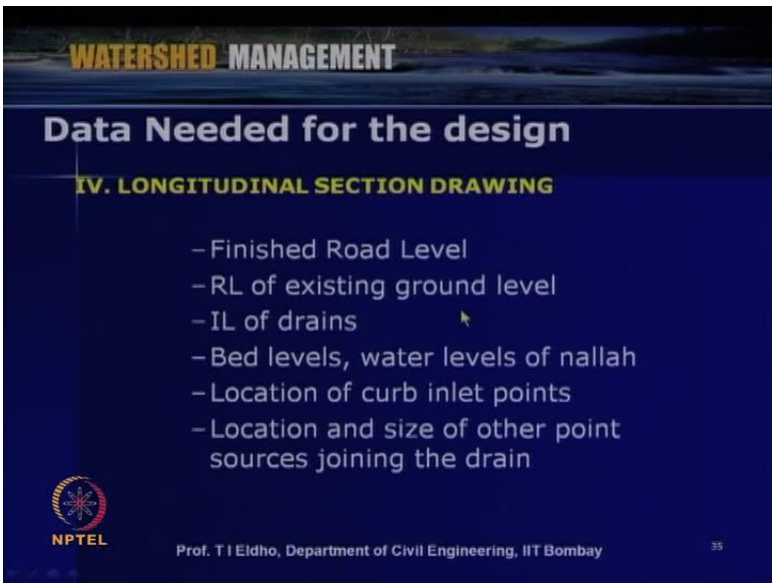

Then detailed plan of the road like length, location of point sources and their discharges, hydrologic mount, reduced level of gourmand levels, then arrows showing the flow direction of storm water in the drains, location of draining nallah, location and size of cross drainage work, locations of manholes and their sizes, and any other data site specific. So, all this data detailed plan of the road and all the data should be available.

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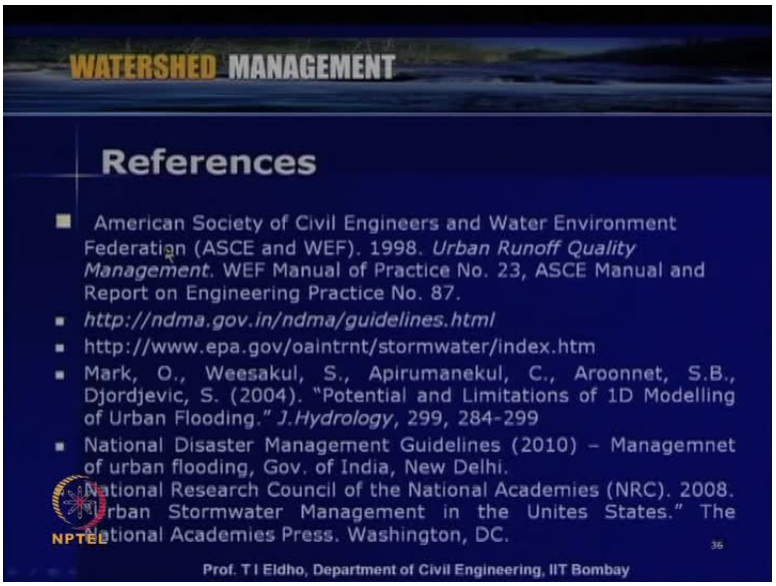

Then longitudinal section drawing like finished road level, reduced level of existing ground level, invert level of drains, bed levels, water levels of nallah, location of curb inlet points, location and size of other point source, joining the drain, so like this. So, all this data should be available. So, when we go for integrated urban drainage system is designed, so including the roads side drains and then the nallah system or the channel system.

So, we should have integrated drainage design plan so that the flood effective. If any possibilities, where that can be reduced, and then, we can have a better management plans and better design so that there is no flood problems as far as area is concerned.

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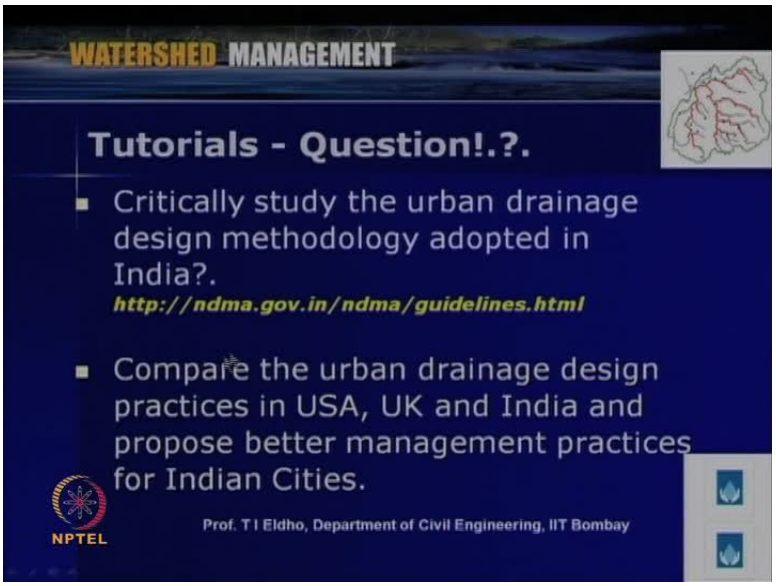

For today's lecture, some of the important references are shown here. Then, before closing the lecture, some tutorial questions and assignment questions - critically study the urban drainage design methodology adopted in India. Some details you can see in this website. Compare to urban drainage design practices in US, UK and India and propose better management practices for Indian cities.

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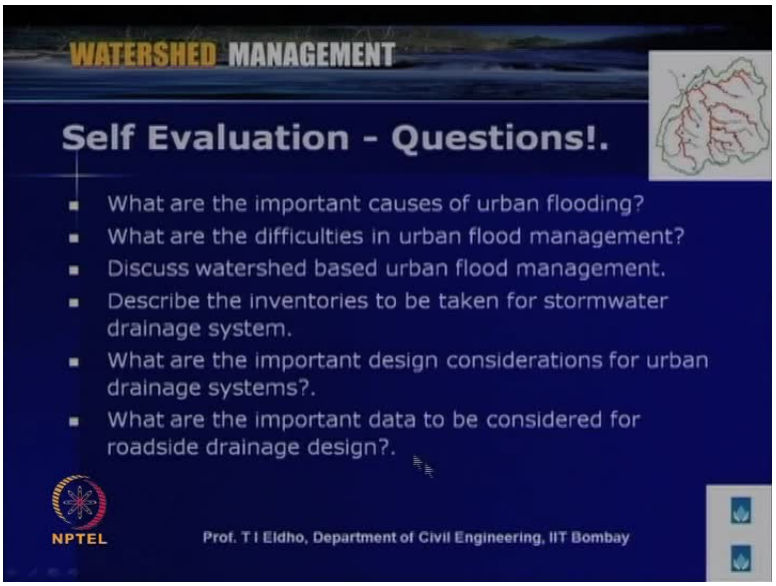

Then few self-evaluation questions - what are the important causes of urban flooding? What are the difficulties in urban flood management? Discuss watershed based urban

flood management? Describe the inventories to be taken for storm water drainage system. What are the important design considerations for urban drainage systems? What are the important data to be considered for roadside drainage design?

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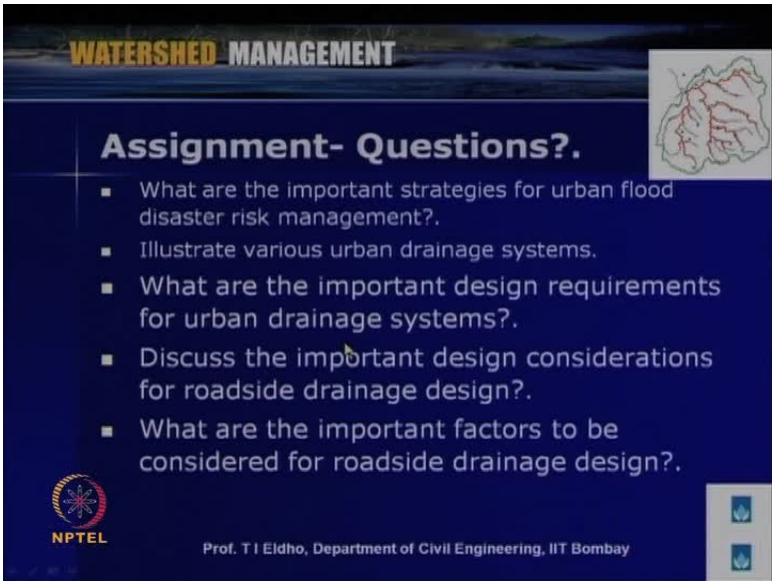

So, all these question you can easily answer by going through today's lecture. Then few assignment questions - what are the important strategies for urban flood disaster risk management? Illustrate various urban drainage systems. What are the important design requirements for urban drainage systems? Discuss the important design considerations for roadside drainage design? What are the important factors to be considered for roadside drainage design?

So, this question also you can answer by going through today's lecture. So, what we discussed today is urban drainage design, and then, integrated design system by considering all the aspects including the roadside drains, nallah system or the channel system so that we can have an effective drainage design. Thank you very much.