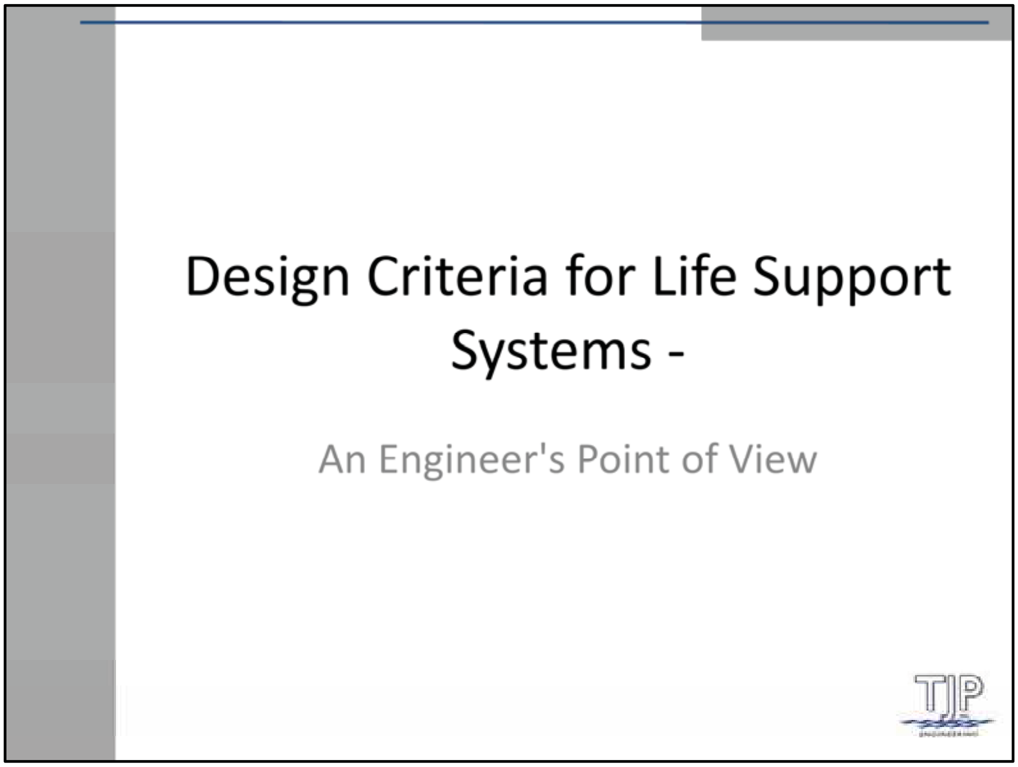
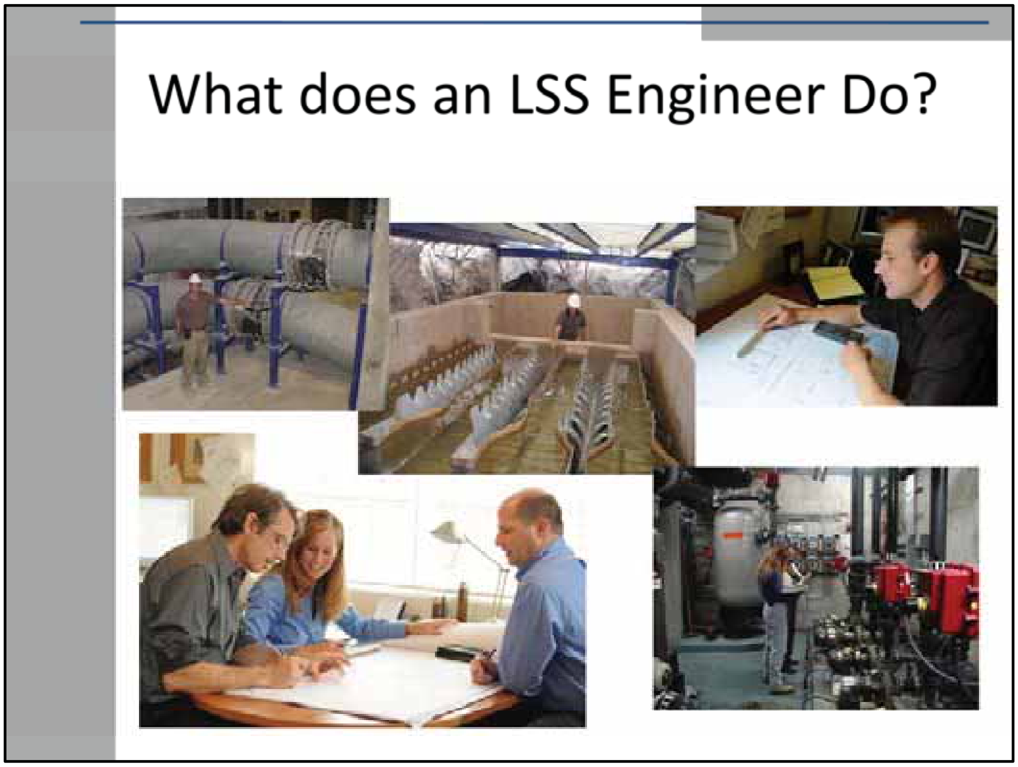
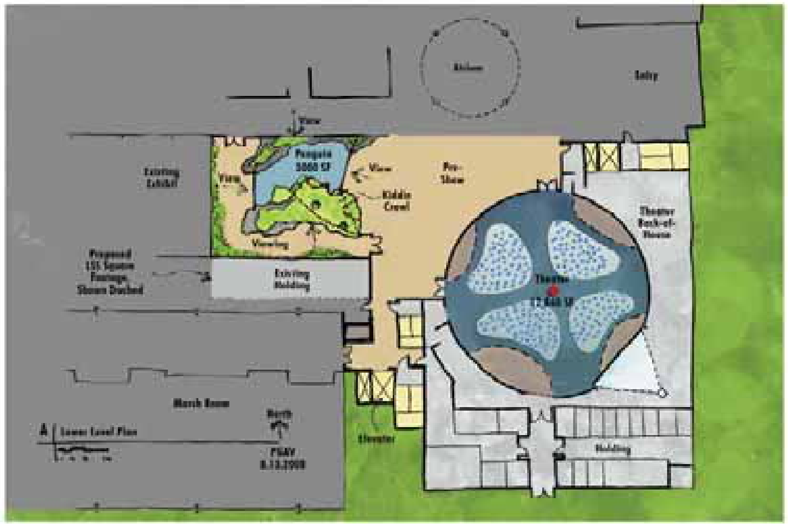


Many of you have worked with us LSS engineers over the years and you have probably wondered how we go about developing a process for a particular exhibit. In my talk today I'm going to discuss the basic design criteria we work from and, more importantly, the kinds of input and communication we need with the end user (you operators) to come up with an optimum LSS for your exhibit and your facility. You've probably noticed in working with an LSS engineer that we ask lots of questions – and some of those questions may seem a little strange at times. My intent with today's talk is to share with you the types of information we are looking for in developing our design and how we use this information in making design decisions. So, when you see us scribbling notes and plugging numbers into our fancy calculators – you'll have a pretty good idea what we're up to.

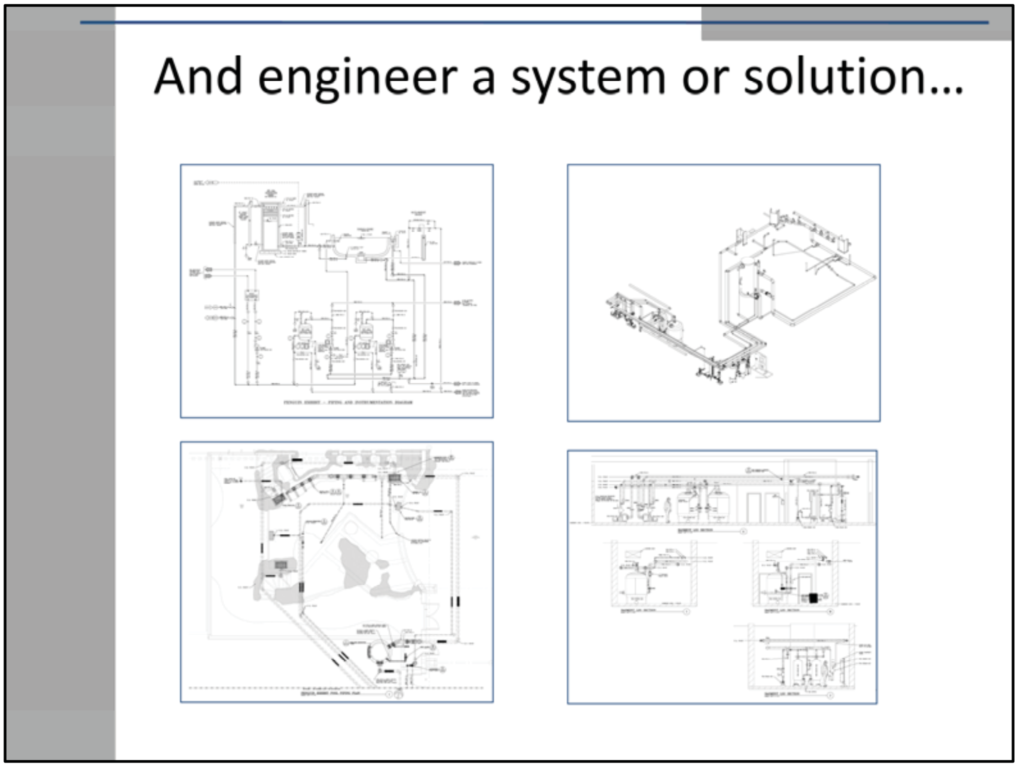


So – what is it that LSS engineers firms do? This is probably what you're used to seeing – us with our plans and wandering around on the jobsite. These are some engineering action shots…

We start with an idea or problem..



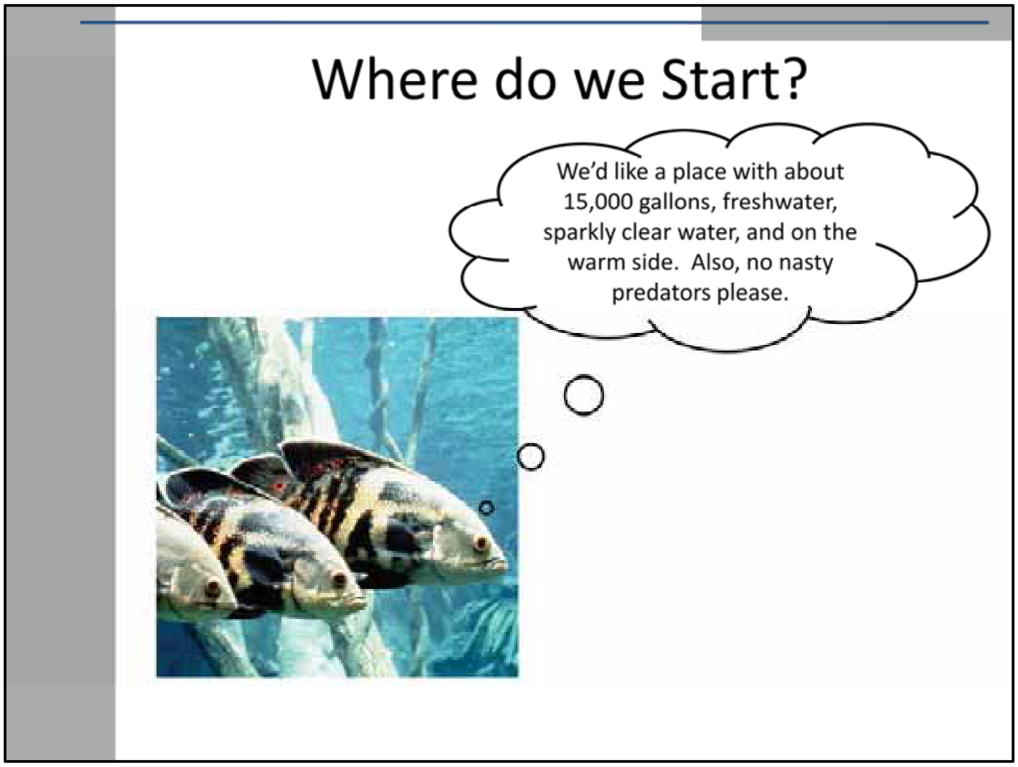
We start with a concept or idea. Or we start with a problem – something like "I have this existing pool and the water, it doesn't look so good." This schematic drawing is where we started for the National Aviary's new Penguin Exhibit and it is pretty typical about where we start out.



We take the idea and figure out how to turn it into a constructible system. In the course of taking a project from the napkin sketching stage through construction and subsequently startup we do loads of “classical” engineering – selecting equipment, detailing out the process, developing models for hydraulics analysis, integrating our piping and equipment into the building or site, coordinating our work with the architect, structural engineer, MEP, and other disciplines, sizing all the piping, evaluating dynamic operating scenarios like power outages and equipment failures, etc.

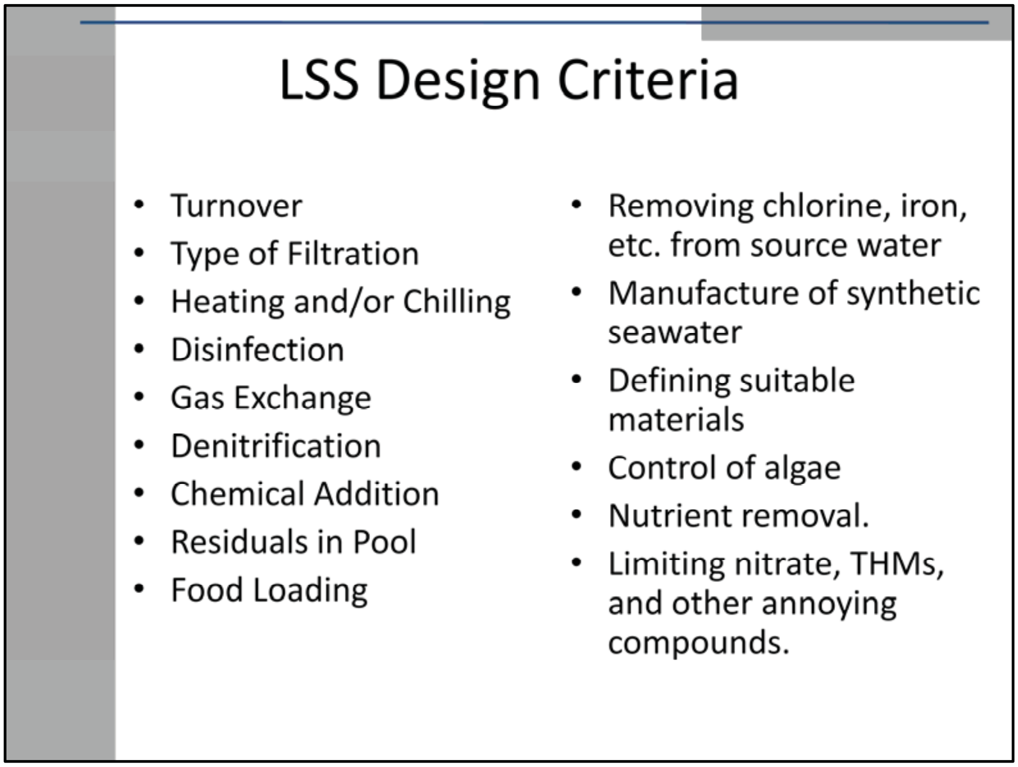
To be part of a completed project

And the end result is part of a completed project.



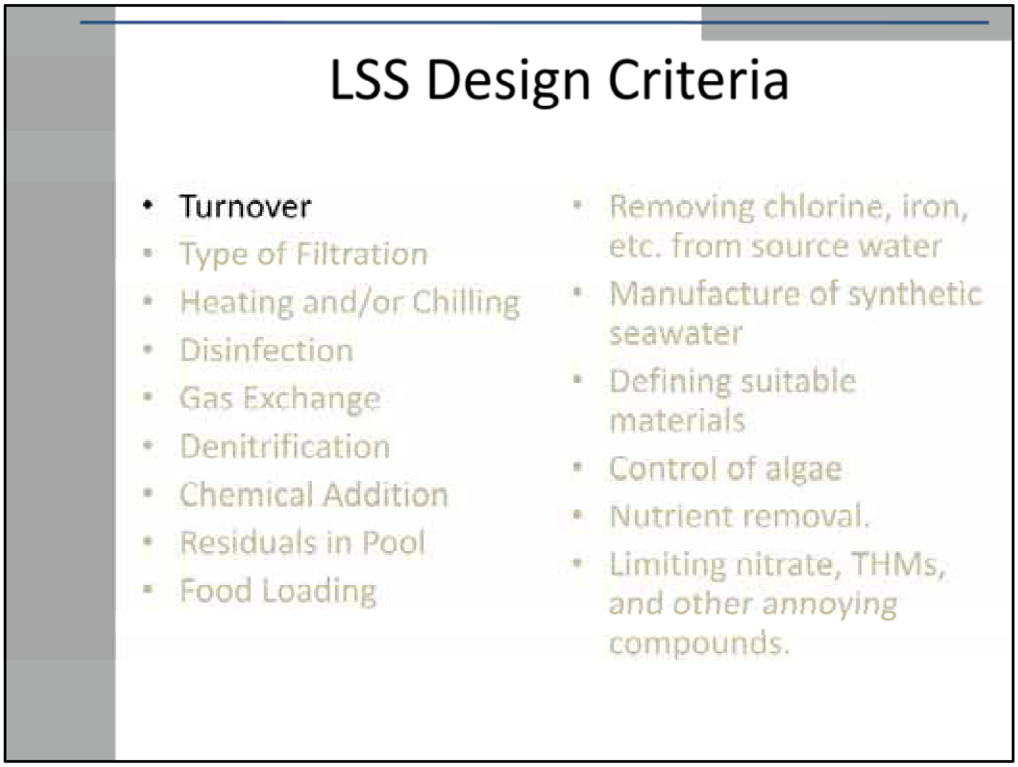
Typically we start the project with very basic information – how big is this pool? What is going to be in the pool? Saltwater or freshwater? Sharks or Stellar Sea Lions? What is our client doing with this pool? Is this a centerpiece exhibit with 100 foot underwater views and regular dive shows, or is this a back of house holding pool with look down viewing?

We use this information to develop the design criteria for the exhibit.



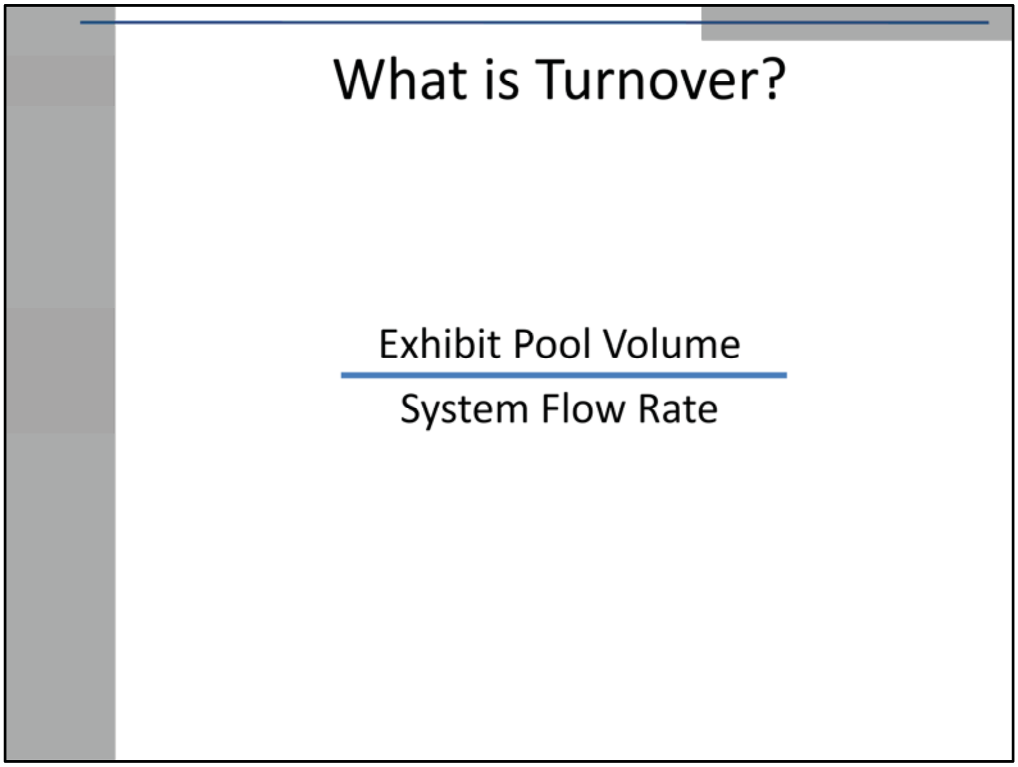
When Roger first suggested this topic, I started thinking about all the design criteria we could talk about...this list could fill a few slides really.

Basically the criteria is a summary of the water quality objectives for the exhibit, process characteristics, and unit process characteristics. It is important we define these things early on in the design and that we communicate them to you guys – the client. This information is generally included in a narrative or "Basis of Design" document generated at the beginning of the project, and updated along the way at subsequent design phases. I know these can be a bit dry to read – its not really a good John Grisham novel – but its important that you check this stuff out and make sure what your engineer is assuming and providing matches with you circumstances and expectations.



But, since we only have 30 minutes I've scaled this back to focusing on turnover. The objective of my talk today is to share with you how we consider this particular design criteria.

It is important though to keep in mind that all this criteria are related to one another and have impacts on each other.



One of the first things we figure out when we start a new system is the turnover. Just to be clear on how we consider turnover, we define it as the exhibit pool volume divided by the system flow rate. I have heard some people look at it in terms of the total system volume, but at TJP we consider the pool volume for a few reasons:

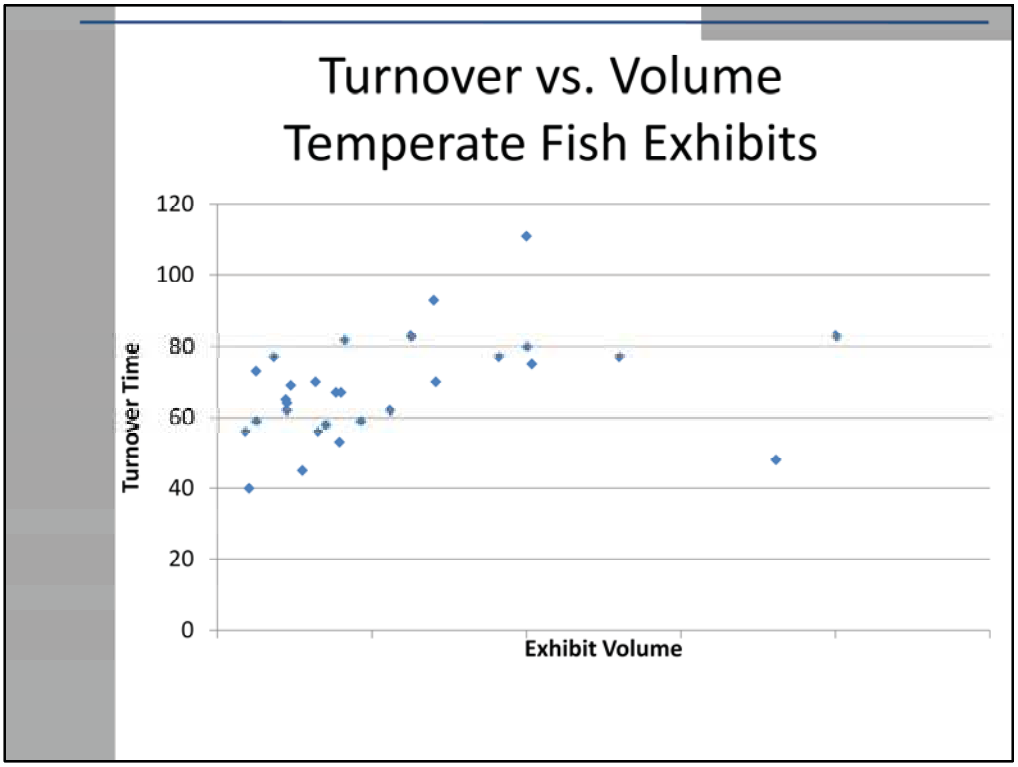
1. First, all our data that we've used over the years to evaluate turnovers is based on exhibit pool volume
2. Second, it is a more practical parameter to work with particularly at the beginning of a project when very little information has been developed.

What Factors Impact Turnover?

- Volume
- Occupant Species and Loading
- Type of Filtration
- Viewing Situation
- Type of Tank
- Temperature
- Makeup Water Condition
- Location

So – how do we come up with our turnover rates? I've listed the key factors here.

Volume – typically as pools get larger their turnovers get longer
Occupant Species – this on is pretty obvious, 20,000 gallons with a couple of alligators is going to be much easier on its LSS than 20,000 gallons with 30 penguins.
Occupant Loading – this one is also pretty obvious, 30 penguins are going to be easier on the LSS than 60 penguins.
Viewing Situation – most of you are familiar with the difference between UW viewing and look down viewing. A good practical example of this is jumping into a swimming pool with swim goggles on. While you're standing on the side of the pool it looks nice and clean and clear. Then you dive in with your goggles on to swim a bit and notice that you can't see far underwater.
Type of Tank – what I mean by this is what is our tank configuration and how it is being used. A roundish ray tank used for dive feeding shows – like Ray Bay at Ripleys Aquarium of the Smokies will need a more aggressive turnover than a lightly loaded, narrow, rectangular tank.
Temperature – warmer tanks tend to need more rapid turnover than cooler tanks.
Makeup Water Condition – when you have a continuous flow of clean fresh makeup water it takes a load off the LSS and you can have longer turnover times, for example the OBW tank at Monterey Bay Aquarium
Location – is this tank outside surrounded by cottonwood trees or is this tank inside a controlled aquarium environment?

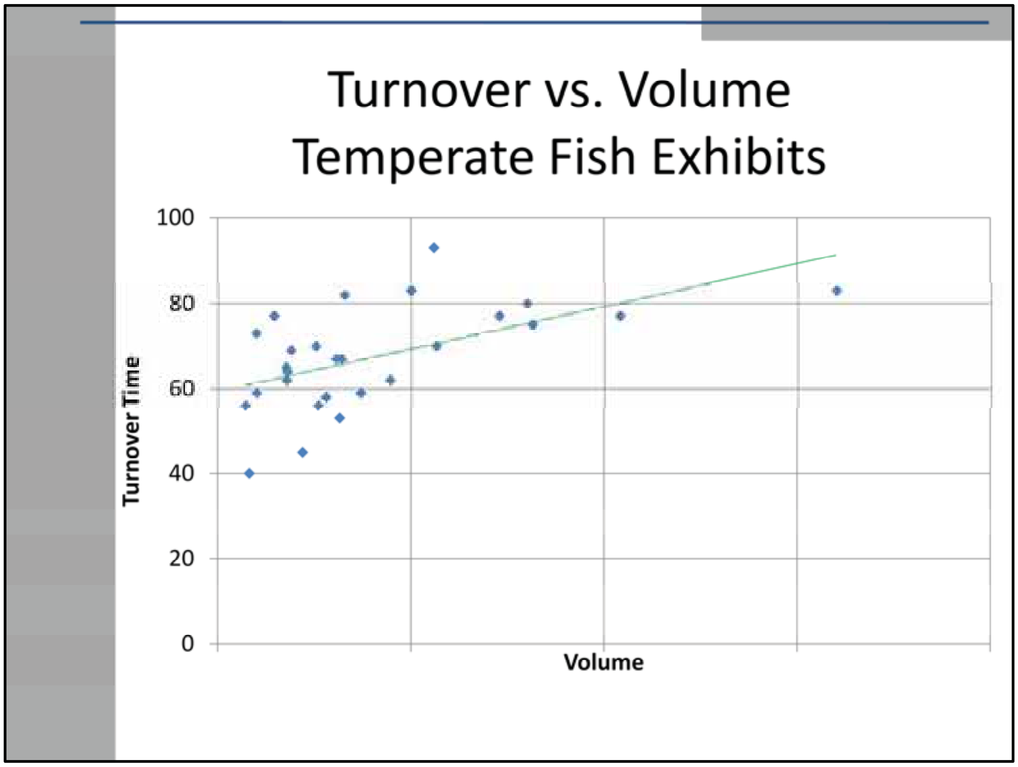


We prepared this graphic to demonstrate a sample of turnover rates. What we have here is data from a sample of thirty LSS for temperate fish exhibits between 50,000 and 800,000 gallons. We have data points here for systems that are over 30 years old and systems started up in the last couple of years. These are tanks with similar collections to what Moody Gardens has here in their Caribbean Reef over in the Aquarium.

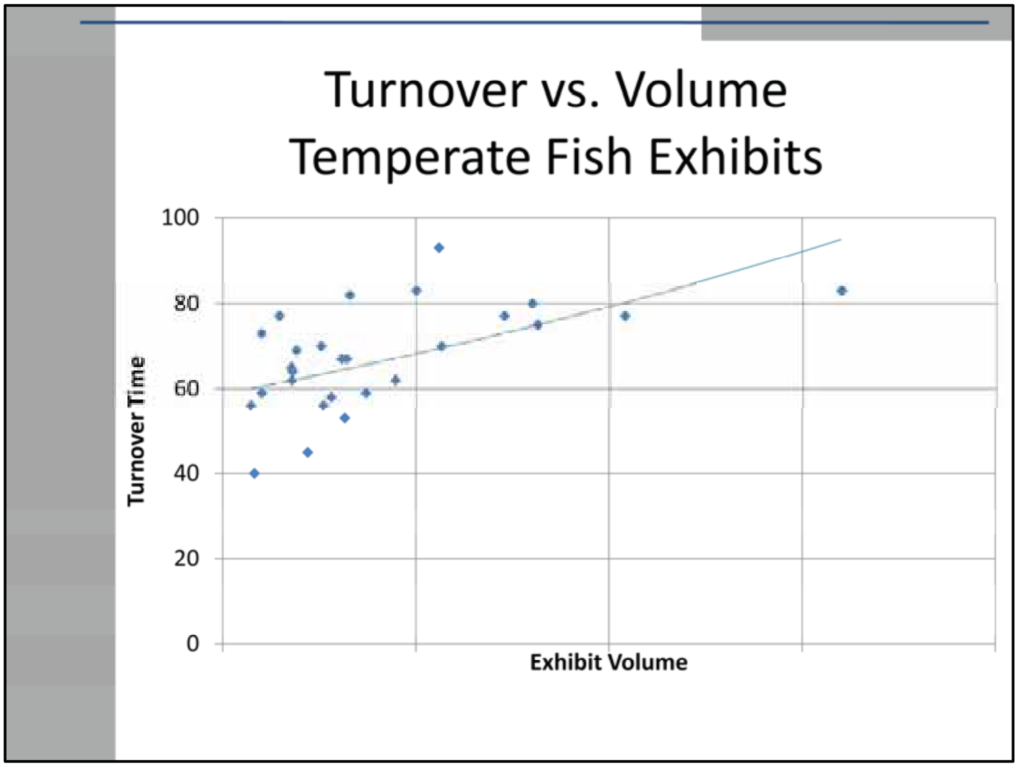
So when you first look at this graphic without knowing anything about the discrete data points it kind of looks like we've got points all over the map. However, once you know a little something about each exhibit, where these points chart relative to one another starts making sense.

Also, today I've limited the scope of my talk to how we establish turnover today. My associate Joel Johnson and Jim Ring from RCK could give a whole separate talk on the history of coming up with turnovers…turbidity equations, smoky backroom lunches at the Godfather, etc.

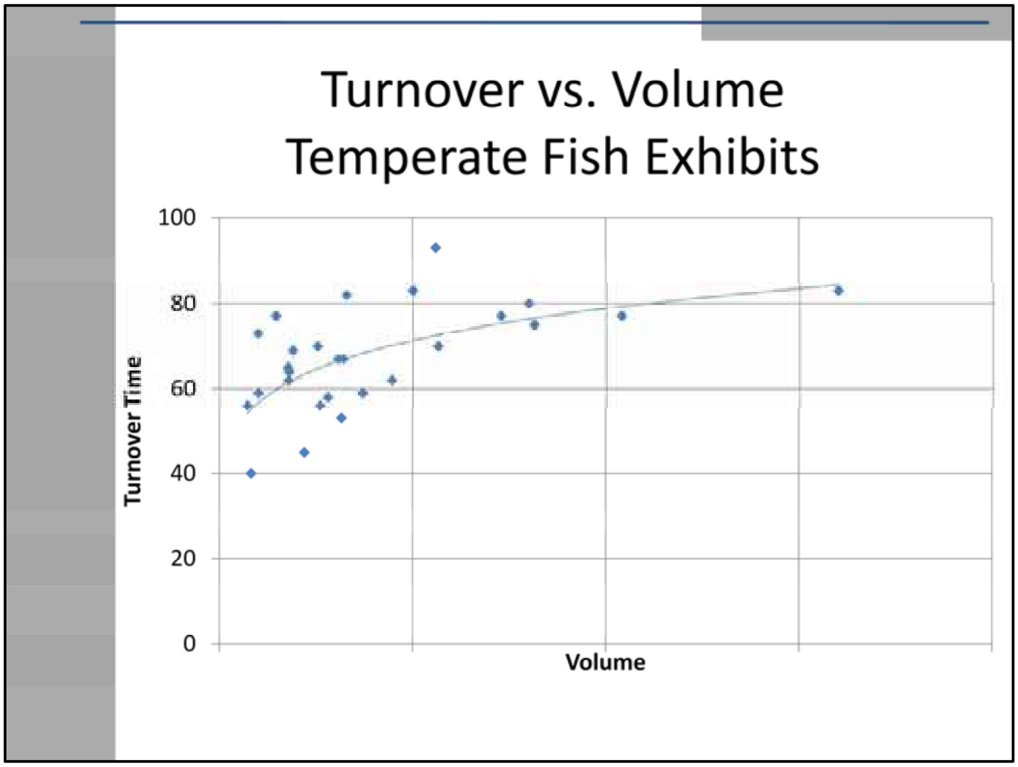
Today we have the luxury of data which has been collected over the last 30 to 40 years. We use this data as a starting point for establishing turnover on a new exhibit.



If we toss out a couple of outlier data points, we can create some pretty nice trend lines comparing volume and turnover. Here is the data with some simple linear trend lines and you can see how the turnover increases with increased volume.



To be a little more “refined” with the data we’re using, here is a 2nd order or exponential trend line. You can see how we engineers also love data fitting equation software with excel to look at the data.



And, here is our preferred trend line for this particular data set – this is a little more representative. In developing a turnover for a new exhibit, I would start with using a graphic like this for a first estimate.

This data set is just for one specific exhibit type – we look at all the exhibits we work on (hippos, cetaceans, reptiles, etc) in a similar way. If I was designing an alligator or dolphin exhibit, I would be using a totally different trend line.

Its also important to remember that picking a point off a trend line is just the beginning in looking at turnover. Now you have a "ballpark" of where you'll start. The next step is to look at other factors.

Occupant Species and Turnover

Obviously what is living in the tank is going to have a major impact on our determination of the optimum turnover.

The occupant species factor is generally accounted for when we select which volume vs. turnover curve we are going to use for our initial selection. Our approach with a Beluga is going to be quite different from our approach to a Hippo.

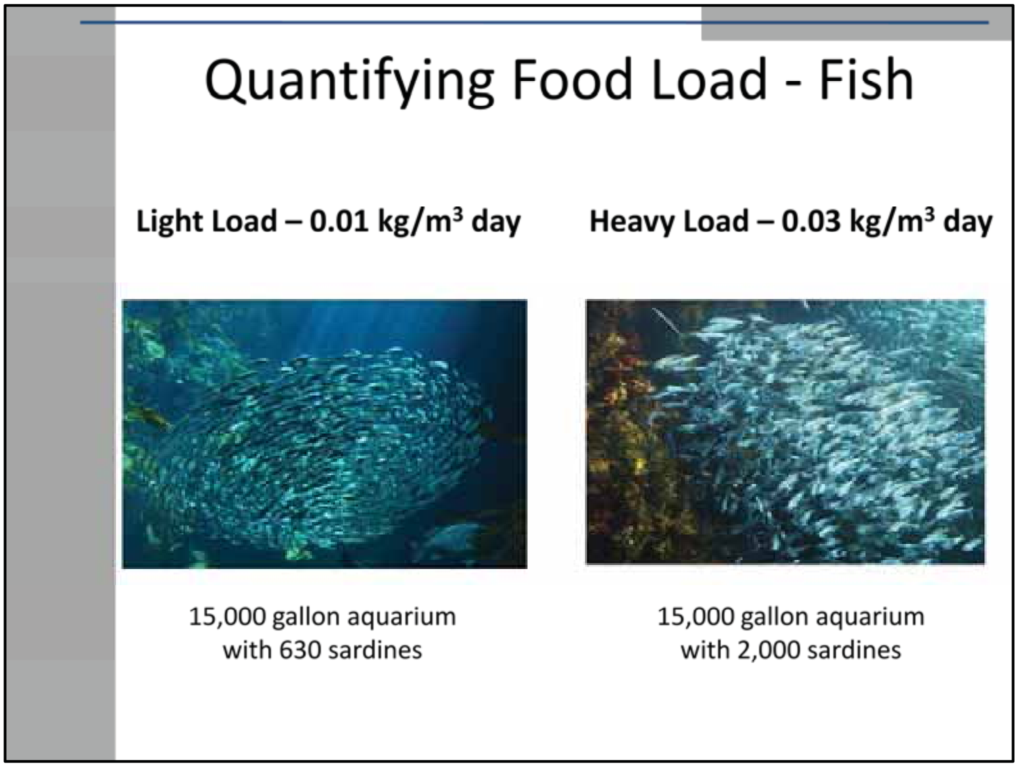
Fish Food and Turnover

Look at all this delicious fish food. The loading on the pool is as important to us as the volume and occupant species when it comes to determining turnover and other design criteria.

One of the criteria we use to evaluate how heavily an exhibit LSS is loaded is by looking at the quotient of animal feed mass and pool volume. Generally we well ask for any information available about anticipated feeding – what will the feed be, feeding frequency, and mass per feeding. We take this information and we look at it a couple of ways. We consider what is the average daily load in terms of kg/cu m and what are the peak loads in terms of kg/cu m.

For many species, the food mass and the food load ratio are used in engineering several aspects of the LSS – we consider it when determining turnovers, sizing the ozone system, anticipating filter operations, and sizing the denitrification process. For us it is pretty critical information in developing the design.

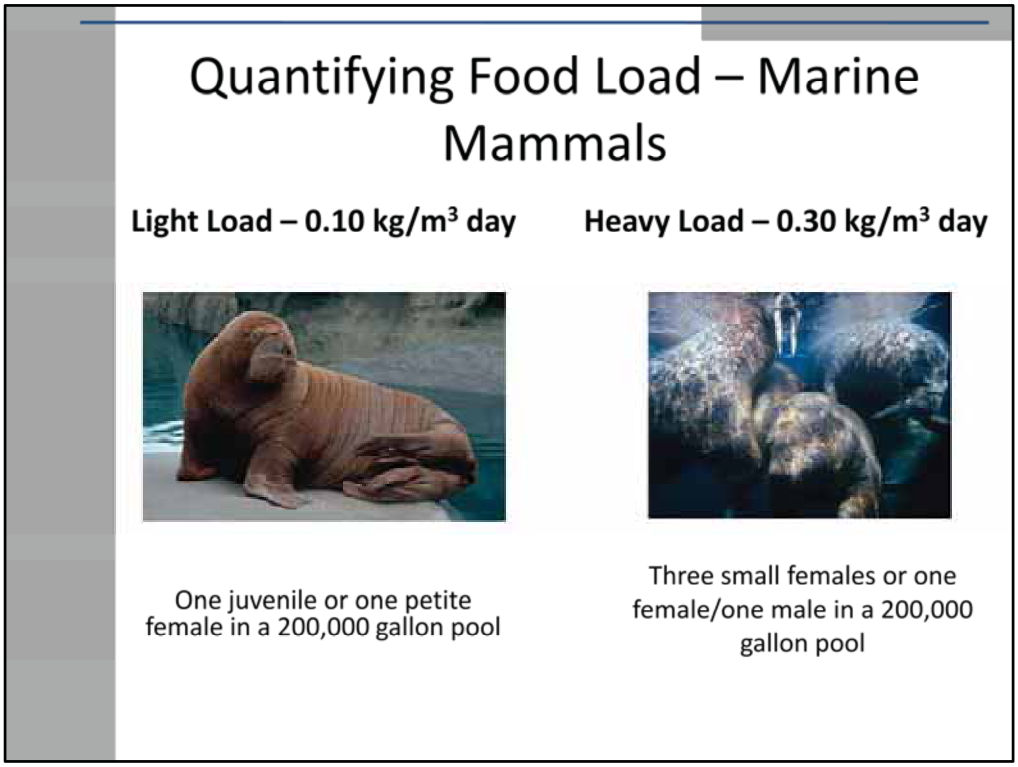
However, it is important to understand that what the animals are eating is as important as how much. When we're designing a system we're looking for information in terms of how many kg/day or kg/feeding, but we are also looking for information on what are the animals being fed. One good example of this is when you look at Hippos – the impact of a pellet diet on the LSS is different from the impact of a hay and alfalfa diet. Another example is brine shrimp vs. chunky fish food. Often the aquarist will toss the brine shrimp into the pool with its soupy broth so it has a very different load on a system when compared to chunks cut from fish fillets.



We quantify food load differently for different types of animals. Also, these numbers – like the “Pirates Code” from “Pirates of the Caribbean” - are more of a guideline.

With fish we consider a lightly loaded tank to have an average food load of 0.01 kg/m3. In practical terms, this would be like have 630 sardines in a 15,000 gallon tank.

A heavily loaded tank has an average fool load up around 0.03 kg/m3. Using our example, this is like having 2,000 sardines in a 15,000 gallon tank. On a side note, with schooling fish like sardines we sometimes see exhibits with loads as heavy as .1 kg/cu m – which is significant. These are the tanks where they sometimes but oxygen injection on the tank to keep the DO up during and after a feeding.

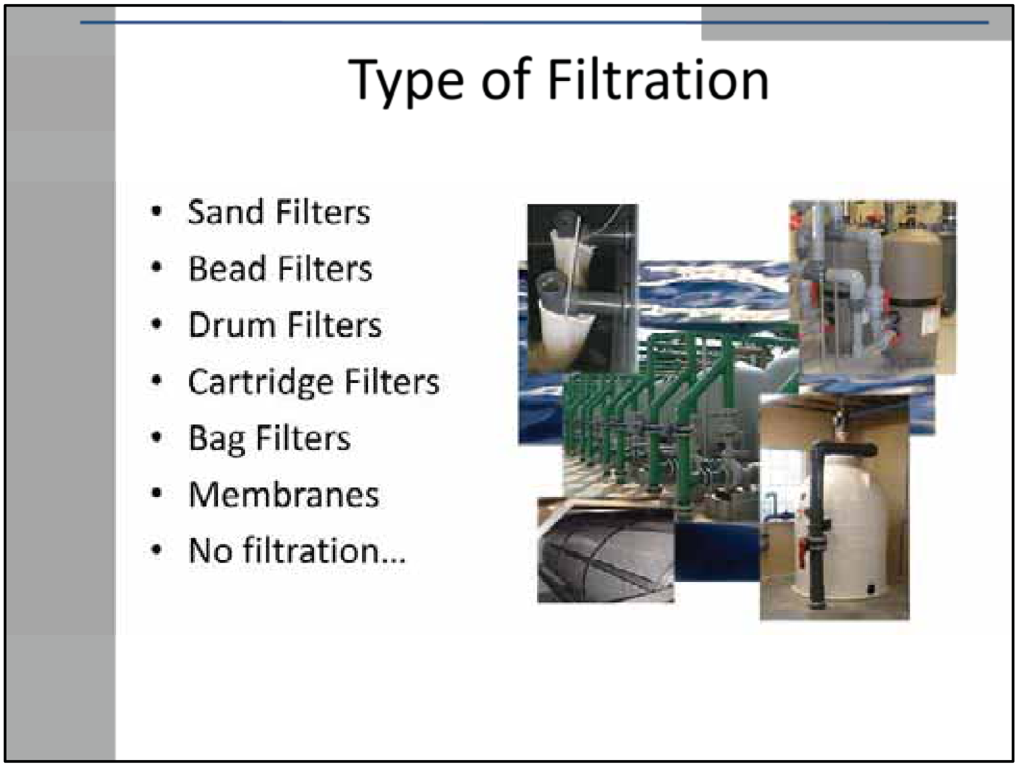


Marine mammal exhibits have higher food loading – roughly and order of magnitude higher.

We consider a lightly loaded tank to have an average food load of 0.10 kg/m3. This is like having a juvenile or small female walrus in a 200,000 gallon tank.

A heavily loaded tank has an average fool load up around 0.30 kg/m3. This is like having 3 small females or 1 male/1female in a 200,000 gallon tank.

An interesting thing to note with marine mammal food loads – some species will almost always have a light load while others will almost always have a heavy load. A good example is comparing dolphins and walrus. Dolphin exhibits are always on the light loading end of the spectrum because they are social animals and you only have a certain number in a given volume of water. The opposite extreme of the spectrum are walrus, they almost always have a heavy load based on their mass, food intake, and typical exhibit volumes.



The type of filtration we are going to use also plays into determining turnover.

We have quite a variety of filtration technologies to choose from and this group is familiar with these options. When I talk about “filtration” here I’m referring to mechanical filtration – processes that form a physical barrier to remove suspended particulate matter.

I have included on my list a “No filtration” option as well. There are successful exhibits that do not use mechanical filtration – for example Roger from MBA has a penguin exhibit that is fractionation only.

As your LSS engineer our role is to thoroughly understand all these technologies and develop our LSS process around the most appropriate approach for a given application. Once a decision is made with respect to our type of filtrations, we factor this into determining turnover.

Type of Filtration and Turnover

- Finer particulate removal generally equates to longer turnover times

Filtration Technology	Particulate Removal Size (microns)	Particulate Size in Perspective	Influence on Turnover
Bead Filters	50	Baking Flour	Shorter
Sand Filters	10	Talcum Powder	Moderate
Membrane Technology	Ultrafiltration – 0.01 to 0.1	Tobacco Smoke – 0.01 to 1 micron Bacteria (Cocci) – 2 micron	Longer

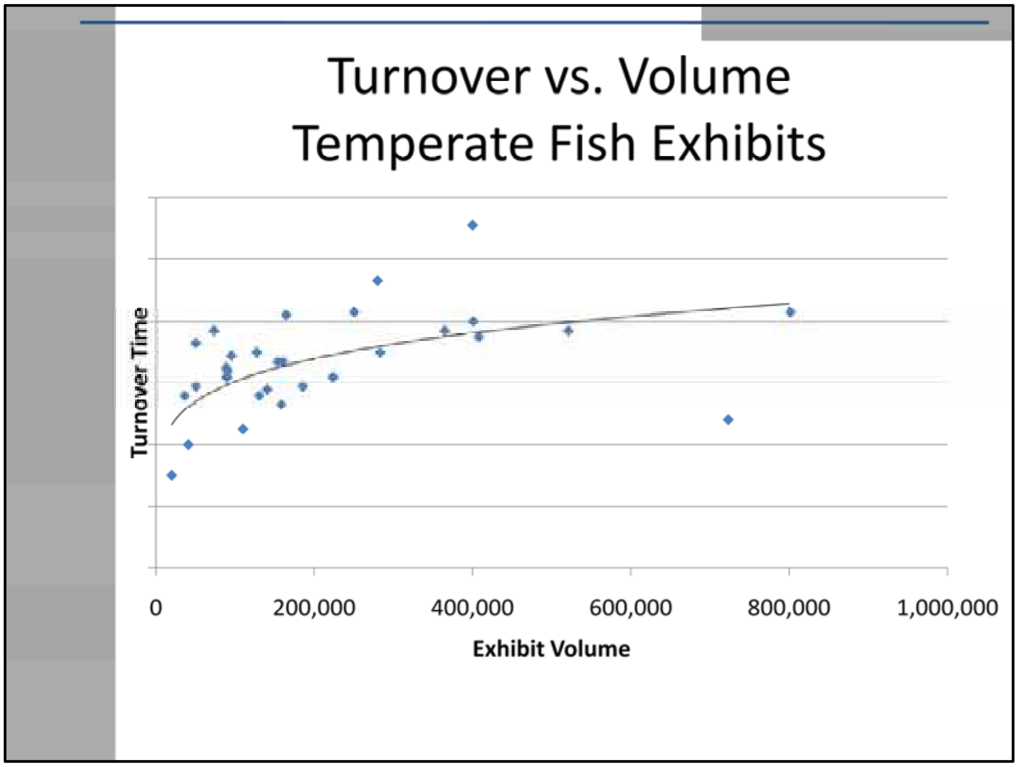
Generally speaking, filtration technologies that remove finer particulate can operate with a long turnover time.

We have this table to illustrate a few of our options, the particle size they can remove by mechanical filtration, a reality check on what that particle size means, and the influence on turnover.

What about a system with Multiple Pools?

Cetaceans are a good example of a system with multiple pools – you may have a show pool with a massive volume and intermittent use, several back of house holding tanks, and smaller medical pools that have the potential for extremely heavy/nasty loading. How do we look at that?

First, we establish the overall turnover for the total volume based on the factors we've discussed. Then we consider distributing the system flow to the various pools based on their individual characteristics. For example, that medical pool where you may be dealing with blood and barf is going to be designed for very rapid turnover (and the ability to isolate) while the show pool will work effectively with a longer turnover.



So, we start with this general curve based on volume to get us in the ballpark of about where an exhibit should be, then we ask lots of questions, evaluate the other factors we've discussed, and refine the design to utilize the appropriate turnover. Please keep in mind that this curve is just representative of one particular type of exhibit.

Questions?

Thank you for your time – and do you have any questions?