Methods for Commercial Decision Tools:

Modeling the Combined Effects of Snapper-Grouper Amendment 37 Proposed Management Measures for Commercially Caught Hogfish:
Modification to the hogfish fishery management unit, fishing level specifications for the two South Atlantic hogfish stocks, rebuilding plan for the East Florida/Florida Keys stock, and establishment/revision of management measures for both stocks.

LAPP/DM and Social Science Branches
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Introduction

Amendment 37 proposes alternatives that would divide the South Atlantic hogfish stock into a Georgia through North Carolina stock and an East Florida/Florida Keys stock, each with its own quota and management measures. To model the economic effects to the commercial sector resulting from the various combinations of management alternatives proposed in Amendment 37, it was necessary to both construct baseline landings estimates for each of the new regions and estimate changes in landings under each combination of annual catch limit (ACL), size limit, and trip limit alternatives for each region. In recent years (2012 through 2014), the commercial sector in the South Atlantic has harvested less than 75 percent of the ACL (set at 49,469 pounds whole weight [lbs ww]) each year. Commercial hogfish landings data, by state, provided by the Southeast Fisheries Science Center, were used for baseline landings construction by each proposed sub-region. Analysis of historical landings in the most recent four years of available data (2011 through 2014), reveals an increasing trend for East Florida and the Florida Keys and a more random pattern for Georgia through North Carolina (Figure 1). A time-series model was fit to landings data for the East Florida/Florida Keys sub-region to capture this trend and was used to forecast landings there in future years. For the Georgia through North Carolina sub-region, the average of 3-year landings from 2012 through 2014 was used to predict future landings.

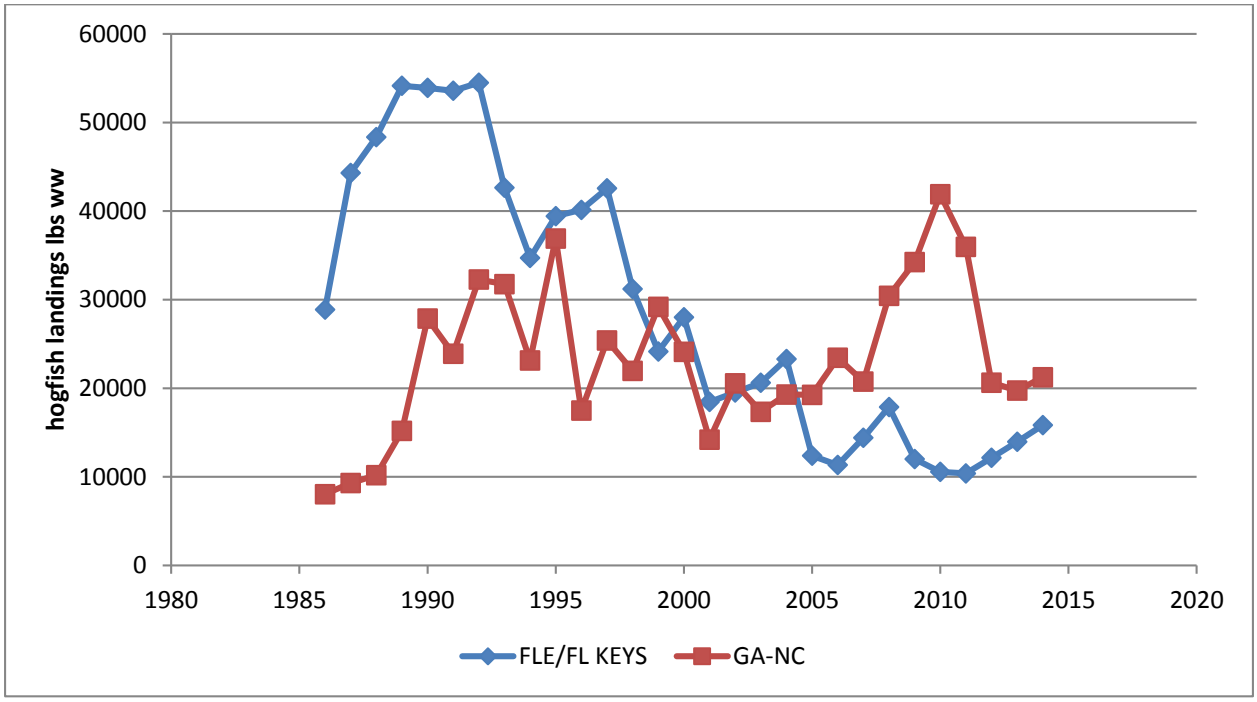

Figure 1. Annual commercial hogfish landings lbs ww by year and region.

East Florida/Florida Keys Model

A SARIMA (seasonal auto-regressive integrated moving average) model was fit to the average daily hogfish landings by month (1997 through 2014) to capture seasonal and non-seasonal trends in the data, especially the recent increasing trend from 2011 through 2014. This approach seemed more appropriate than using an average of recent landings. The SARIMA model was fit to daily average landings by month because of the expectation that season length would become an important comparative factor for analyzing alternatives and daily harvest estimates would be required for this analysis. The rationale for this decision was that the extremely restrictive ACL alternatives proposed in the action were expected to be exceeded regardless of the other proposed alternatives, meaning the only economic effect the minimum size limit and trip limit alternatives would have is on the length of the season, not revenue[1].

Prior to fitting the model, average daily landings by month were log-transformed to reduce the impacts of heteroscedastic errors. During the model identification phase, a Dicky Fuller test and Phillips-Perron unit-root test were performed. Without a constant, the null hypothesis of a random walk could not be rejected. Additionally a simple first order autoregressive model was fit to the data and the magnitude of the estimated coefficient was approximately one, suggesting first differencing was required. Running the tests on the differenced log landings data did show the unit-root had been removed. Autocorrelation plots and partial autocorrelation plots were used to identify candidate autoregressive and moving average terms. Model selection included many iterations of testing with various autoregressive, moving average, and differencing terms.

[1] This assumes that effort, catch rates, and prices will not change in response to management measures, only landings will change. As management measures become more prohibitive, these assumptions become weaker.

Estimated coefficient p-values, Akaike's Information Criterion values and root mean squared errors (RMSE) (in-sample and out of sample[2]) were used for model selection. The best fit and predictions were achieved from a log-transformed (to handle non-constant variance) SARIMA model, differenced by 1 and 12 (to handle non-stationarity and seasonality), a first-order autoregressive term, and a first-order moving average term. As seen in Figure 2, because this time series has an underlying random walk pattern, the dynamic forecast intervals expand rapidly as we project further into the future. Nevertheless, the short-term estimates are expected to be a better prediction of future landings than the average of 2012 through 2014 landings (as used for the Georgia through North Carolina area), given the clear increasing trend in daily landings in recent years. Model estimation was performed in both Stata and SAS, yielding almost identical results.

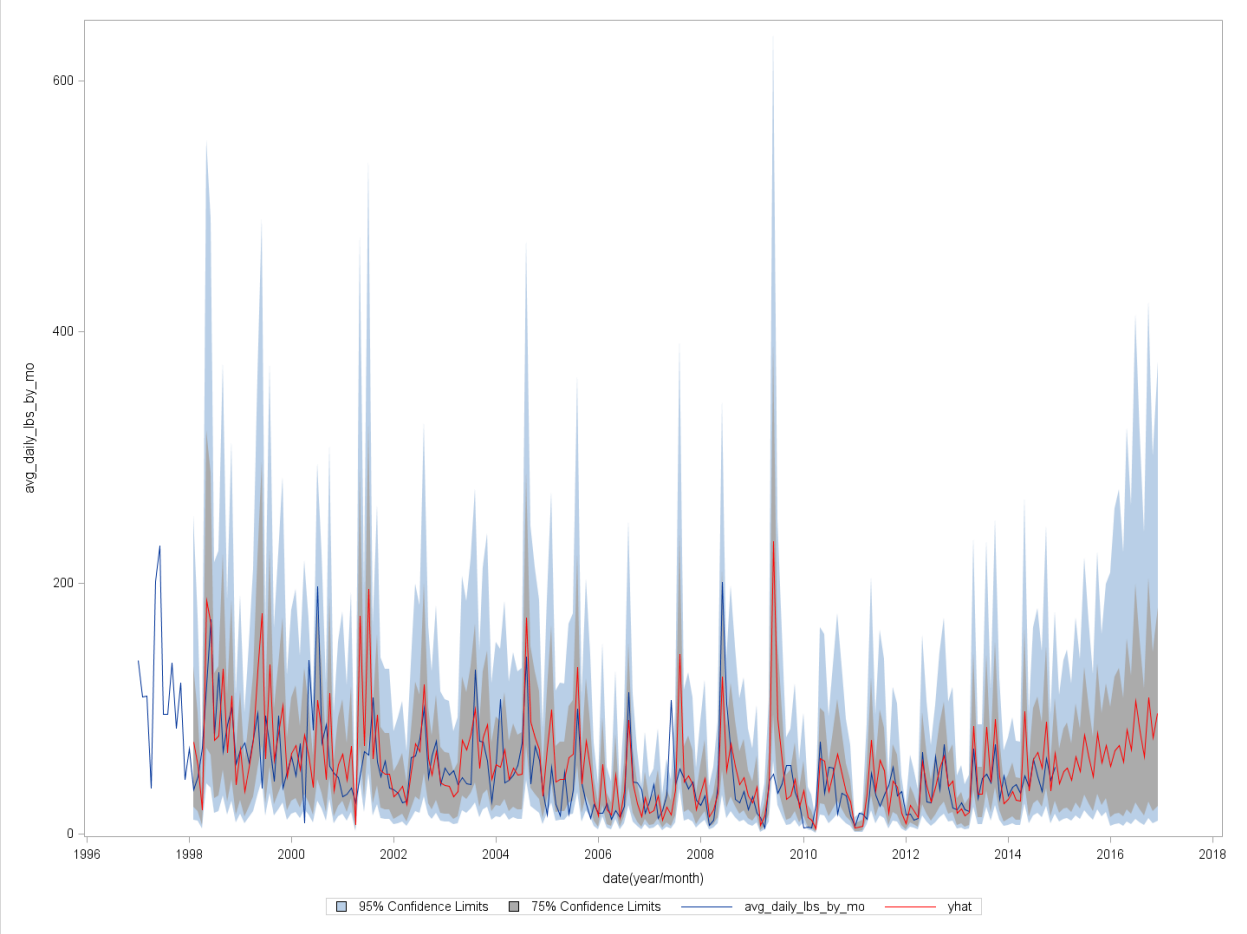

Figure 2. Average daily hogfish landings by year and month with SARIMA model predictions and corresponding forecast intervals.

Because the proposed ACL sub-alternatives for the East Florida/Florida Keys region are substantially lower than projected baseline landings, it is expected that the quota would be harvested in full during the year and an in-season quota closure would occur, even under the

[2] For the out-of-sample tests, the SARIMA model variations were re-fit without 2014 observed values and forecasts of 2014 were compared to this hold-out sample via RMSE.

most restrictive combination of minimum size limit and trip limit alternatives. This means that the selection of the ACL alternative is the driving factor in terms of changes in revenue from the baseline and the other proposed management measures will only have an effect on the season length. To estimate changes in revenue resulting from each of the ACL sub-alternatives, first the baseline landings and revenue were constructed from the projected annual landings estimated by the SARIMA model. The projected baseline landings for 2016 were 28,406 lbs ww[3]. Although the action is not expected to be implemented until 2017, confidence in model forecasts become increasingly low beyond 2016 and so 2016 values are used as the best estimate of daily landings in 2017 as well[4]. These baseline landings were then multiplied by an average annual price (2012 through 2014) of hogfish per pound ww of $3.74 (2014 dollars; Source: ACL commercial data set, July 20, 2015)[5]. Because it is estimated that the proposed ACL alternatives would be exceeded under any combination of other alternatives, to calculate expected effects to commercial revenue, each ACL alternative value was multiplied by the aforementioned price and a difference was taken between this value and the baseline revenue value (Table 1).

To model season length it was necessary to project landings at the daily level. This was done using the average daily landings by month for 2016, as predicted by the dynamic SARIMA forecast. Again, given the increasing forecast interval for the SARIMA model, it did not seem prudent to project beyond 2016, and therefore, 2016 will serve as a best estimate for 2017 daily landings. Daily landings estimates were multiplied by one minus the estimated percent reduction in landings resulting from each size limit increase, times the estimated percent of status quo landings remaining after each trip limit decrease. Because the model applies these percent changes to projected landings independent of each other, it may overestimate total reductions[6]. For a description of the percent reduction estimation processes, see Appendix A. These daily estimates were then summed up until the day before the cumulative landings were projected to exceed the proposed ACL for 2017, at which time a quota closure would be expected to occur and hogfish landings would cease. Season length was calculated as the number of days up until the day at which the quota was projected to be exceeded (Tables 2-4). Under the status quo ACL, the season length would be expected to be 365 (plus one if leap year) days.

[3] This assumes that even with the increasing trend captured by the SARIMA model, the overall South Atlantic hogfish stock ACL of 49,469 lbs ww would not be exceeded under the status quo in 2017 and no quota closures would occur.

[4] It is important to note that even the 2016 estimates are highly uncertain because they are greater than 12 periods past the last observed daily average landings value, meaning they are based entirely on the landings values forecasted for 2015.

[5] Because there are many substitute species for hogfish, it is assumed to have a high price elasticity of demand and, therefore, ex-vessel price would not be very sensitive to the estimated changes in landings. Additionally, there has been low fluctuation in price over time and the overall quantity of commercial hogfish landings relative to other snapper grouper species is low.

[6] Fish that are discarded as a result of a higher minimum size limit (MSL) would no longer count towards the trip limit, implying that the reduction in landings necessary to comply with the new trip limit after those discards are accounted for would be lower than it would be under the status quo MSL. Because separate data sources are used to analyze size limits and trip limits, it is not possible to assess the combined effects of these management measures.

Table 1. Estimated revenue under ACL alternatives and change in revenue relative to status quo in first year of implementation (2017).

	ACL (lbs ww)	ESTIMATED REVENUE (2014 dollars)	CHANGE FROM STATUS QUO (2014 dollars)
Alt 2a	3,697	$ 13,826	$ (92,403)
Alt 2b	3,512	$ 13,134	$ (93,095)
Alt 2c	3,327	$ 12,442	$ (93,787)

Note 1: Because the daily-level model works with daily catch rates that are different based on the combination of alternatives, this can result in total expected landings being closer to or further from the actual ACL at the time of the closure. For simplicity sake, the above figures assume that the cumulative landings will be exactly equal to the ACL at the time of the in-season quota closure, ignoring the minor differences in the model estimates.
Note 2: The estimates provided by this analysis are only for the expected year of implementation, 2017. Negative effects would be expected to continue to occur relative to the status quo in subsequent years, assuming constant prices, effort and catch rates; however, these negative effects would be decreasing in magnitude relative to the ACL increases included in the rebuilding schedule.

Table 2. Estimated season length under ACL Alt 2a (3,697 lbs ww) and different minimum size limit and trip limit alternatives in first year of implementation (2017).

	Trip Limit (lbs ww)					
Size Limit (FL inches)	**No limit (Alt 1 - Status Quo)**	**25 (Alt 3a)**	**50 (Alt 3b)**	**100 (Alt 3c)**	**150 (Alt 3d)**	**200 (Alt 3e)**
12 (Alt 1 - Status Quo)	61	97	74	65	62	61
14 (Alt 3a)	121	151	130	124	122	122
15 (Alt 3b)	129	164	140	132	130	129
16 (Alt 3c)	133	186	144	136	134	134
17 (Alt 3d)	136	191	147	138	136	136
14/16 (Alt 3e*)	121	151	130	124	122	122

*3e is a step increase, with an increase to14 in year 1 and an increase to16 in year 3. Model uncertainty is such that year 3 predictions would be highly uncertain. As such, estimates are for year 1 only and match those associated with Alt 3a.

Table 3. Estimated season length under ACL Alt 2b (3,512 lbs ww) and different minimum size limit and trip limit alternatives in first year of implementation (2017).

	Trip Limit (lbs ww)					
Size Limit (FL inches)	**No limit (Alt 1 - Status Quo)**	**25 (Alt 3a)**	**50 (Alt 3b)**	**100 (Alt 3c)**	**150 (Alt 3d)**	**200 (Alt 3e)**
12 (Alt 1 - Status Quo)	58	92	71	62	59	59
14 (Alt 3a)	118	147	127	121	119	118
15 (Alt 3b)	127	159	136	129	127	127
16 (Alt 3c)	131	181	141	133	131	131
17 (Alt 3d)	133	187	144	136	134	133
14/16 (Alt 3e*)	118	147	127	121	119	118

*3e is a step increase, with an increase to14 in year 1 and an increase to16 in year 3. Model uncertainty is such that year 3 predictions would be highly uncertain. As such, estimates are for year 1 only and match those associated with Alt 3a.

Table 4. Estimated season length under ACL Alt 2c (3,327 lbs ww) and different minimum size limit and trip limit alternatives in first year of implementation (2017).

	Trip Limit (lbs ww)					
Size Limit (FL inches)	**No limit (Alt 1 - Status Quo)**	**25 (Alt 3a)**	**50 (Alt 3b)**	**100 (Alt 3c)**	**150 (Alt 3d)**	**200 (Alt 3e)**
12 (Alt 1 - Status Quo)	55	88	67	59	57	56
14 (Alt 3a)	115	142	124	118	115	115
15 (Alt 3b)	124	153	133	126	125	125
16 (Alt 3c)	129	168	137	131	129	129
17 (Alt 3d)	131	181	140	133	131	131
14/16 (Alt 3e*)	115	142	124	118	115	115

*3e is a step increase, with an increase to14 in year 1 and an increase to16 in year 3. Model uncertainty is such that year 3 predictions would be highly uncertain. As such, estimates are for year 1 only and match those associated with Alt 3a.

Georgia through North Carolina Model

Based on historical average annual landings (2012 through 2014), it is expected that none of the ACL alternatives would result in an in-season closure. Therefore, the season length under all combinations of alternatives is expected to be 365 (plus one if leap year) days. The estimated change in landings under the different combinations of minimum size limit and trip limit alternatives for the commercial sector, would also be the same for each of the ACL alternatives. The baseline landings used for the Georgia through North Carolina region were the average annual landings from 2012 through 2014. An average annual price (2012 through 2014) of hogfish per lb ww of $3.74 (2014 dollars; Source: ACL commercial data set, July 20, 2015) was used to generate baseline revenue estimates[7]. To estimate landings under the various minimum size limit and trip limit alternatives, average annual landings (2012 through 2014) were multiplied by one minus the estimated annual percent reduction in landings resulting from each size limit increase, times the estimated annual percent of status quo landings remaining after each trip limit decrease (Table 5). Because the model applies these percent changes to projected landings independent of each other, it may overestimate total reductions[8]. For a description of the percent reduction estimation processes, see Appendix A. These landings estimates were then multiplied by the average price and the difference between estimated revenue and baseline revenue was taken to produce estimated economic effects estimates for the first year of implementation, 2017 (Table 6). Comparable economic effects are expected to continue to occur in subsequent years, assuming no changes in effort, catch rates, or prices. However, for Sub-alternative 2f of Action 8, the reductions in revenue relative to the status quo would be expected to increase with each minimum size limit increase.

[7] Because there are many substitute species for hogfish, it is assumed to have a high price elasticity of demand and, therefore, ex-vessel price would not be very sensitive to the estimated changes in landings. Additionally, there has been low fluctuation in price over time and the overall quantity of commercial hogfish landings relative to other snapper grouper species is low.

[8] Fish that are discarded as a result of a higher MSL would no longer count towards the trip limit, implying that the reduction in landings necessary to comply with the new trip limit after those discards are accounted for would be lower than it would be under the status quo MSL. Because separate data sources are used to analyze size limits and trip limits, it is not possible to assess the combined effects of these management measures.

Table 5. Estimated landings in first year of implementation (2017) for all ACL alternatives and various minimum size limit and trip limit combinations*.

	Trip Limit (lbs ww)				
Size Limit (FL inches)	**No limit (Alt 1 - Status Quo)**	**100 (Alt 2a)**	**250 (Alt 2b)**	**500 (Alt 2c)**	**750 (Alt 2d)**
12 (Alt 1 - Status Quo)	20,534	11,745	16,554	19,339	19,951
16 (Alt2a)	20,406	11,672	16,450	19,218	19,826
17 (Alt 2b)	20,128	11,513	16,226	18,956	19,556
18 (Alt 2c)	19,918	11,392	16,057	18,758	19,351
19 (Alt 2d)	19,398	11,095	15,637	18,268	18,846
20 (Alt 2e)	18,921	10,822	15,253	17,820	18,383
15/18/20 (Alt 2f)**	20,498	11,724	16,525	19,305	19,915

* This assumes that effort and catch rates will not change in response to management measures, only landings will change.

Note 1: Season length here will be 365 days +1 if leap year. Because season length will not be affected, and because there was minimal variability in monthly average prices, changes in landings and econ effects were modeled at the annual level only.

Note 2: Because the estimated landings are not expected to exceed even the most conservative ACL alternative, each trip limit/size limit combination is expected to have the same effect for all ACL alternatives.

Note 3: Trip limit and size limit alternatives will not be considered separately from action to form two management areas, NC to GA and East FL/FL Keys.

**Alt 2f uses a stepped approach to increasing the size limit with an increase to 15 in in year 1, 18 in in year 2, and 20 in in year 3. Given the uncertainty associated with predicting further into the future, the effects are based only on the 15 in size limit increase that would occur in year 1.

Table 6. Estimated change in revenue (2014 dollars) from status quo in first year of implementation (2017) for all ACL alternatives and various minimum size limit and trip limit combinations*.

	Trip Limit (lbs ww)				
Size Limit (FL inches)	**No limit (Alt 1 - Status Quo)**	**100 (Alt 2a)**	**250 (Alt 2b)**	**500 (Alt 2c)**	**750 (Alt 2d)**
12 (Alt 1 - Status Quo)	$ -	$ (32,869)	$ (14,886)	$ (4,470)	$ (2,183)
16 (Alt2a)	$ (479)	$ (33,143)	$ (15,272)	$ (4,922)	$ (2,649)
17 (Alt 2b)	$ (1,520)	$ (33,738)	$ (16,111)	$ (5,901)	$ (3,659)
18 (Alt 2c)	$ (2,306)	$ (34,188)	$ (16,745)	$ (6,642)	$ (4,424)
19 (Alt 2d)	$ (4,251)	$ (35,301)	$ (18,313)	$ (8,474)	$ (6,313)
20 (Alt 2e)	$ (6,033)	$ (36,320)	$ (19,750)	$ (10,152)	$ (8,045)
15/18/20 (Alt 2f)**	$ (136)	$ (32,947)	$ (14,995)	$ (4,598)	$ (2,315)

* This assumes that effort, catch rates and prices will not change in response to management measures, only landings will change.

** Alt 2f uses a stepped approach to increasing the size limit with an increase to 15 in in year 1, 18 in in year 2, and 20 in in year 3. Given the uncertainty associated with predicting further into the future, the effects are based only on the 15 in size limit increase that would occur in year 1.

Appendix A: Methods for estimating percent reductions from trip limit decreases and minimum size limit increases.

Trip Limits

To model trip limits, if total landings of hogfish (lbs ww) per logbook-reported trip (2012 through 2014) were greater than the trip limit being analyzed, trip landings were reset to the new trip limit value, otherwise no changes to harvest were made. Commercial fishermen were assumed to stop targeting hogfish after the trip limit was met. By aggregating these new restricted landings at the desired temporal-level, the percent of status quo landings remaining after each trip limit is implemented can be calculated. Assuming the distribution of trip-level landings remains the same on average in the future, these percent remaining values can then be applied to estimated future landings to predict changes in landings from implementation of such trip limits relative to the status quo.

Minimum Size Limits

Reductions in harvest (weight of fish) were calculated for minimum size limits (MSLs) at 1-inch intervals between 12-20 inches fork length (FL) as follows:

Percent reduction = $G+B/C$, where:
C = *catch in pounds WW,*
G = *weight of fish that are greater than or equal to the MSL, and*
B = *weight of fish smaller than the current 12-inch FL MSL (non-compliance or measurement error).*

The above formula was applied to average monthly landings by fish size (2012 through 2014) from the Trip Interview Program (TIP)[9]. In some instances, observations were pooled across nearest months until a sample size of 30 fish (in numbers) for the status quo was achieved. These monthly percent reduction values were used in the East Florida/Florida Keys model. For the Georgia to North Carolina model, the above formula was applied to average annual landings by fish size (2012 through 2014) from TIP. Assuming the distribution of trip-level landings by fish size remains the same on average in the future, these percent reductions can be applied to estimated future landings to predict changes in landings from implementation of such size limits relative to the status quo.

[9] http://www.sefsc.noaa.gov/interview/userguide.htm